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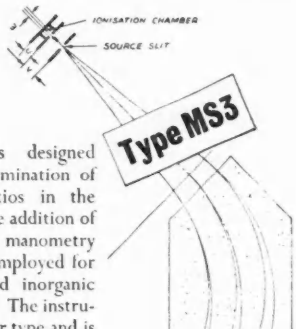

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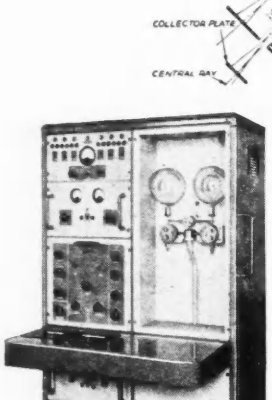

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MARCH 1953 VOLUME XIV NUMBER 3

THE PROGRESS OF SCIENCE

BRITAIN'S FIRST BREEDER PILE

Question-time in the House of Commons on January 26 found the Minister of Supply being asked what progress had been made towards solving the problems of using atomic energy for industrial purposes and for transport. The Minister's reply did not offer any prospect that atomic power stations are likely to materialise very soon, but he did give some hard facts which indicate that Britain is making steady and sure progress in the atomic field, the kind of progress which should guarantee that Britain will be one of the first countries to harness atomic energy for power production.*

On an occasion such as this, when a minister is dealing with a technical subject, his words may be taken as embodying the views of his technical experts, and hence they carry the weight which a statement from Sir John Cockcroft or Lord Cherwell covering the same ground carries. He started by saying that the most certain method of generating power from atomic energy would be to build an improved type of natural uranium reactor enclosed in a pressure shell, the heat produced being transferred by a gas under pressure through a heat exchanger to a conventional electric generator. As a by-product this would yield plutonium, which could be used as fuel for further reactors. The potentialities of such a reactor are being actively studied, and if the prospects are shown to be favourable the Ministry of Supply will consider constructing an experimental atomic power station of this kind.

The 'breeder-reactor', a reactor capable of creating more fissile material than it consumes, is a more advanced concept, and the pile which breeds atomic 'fuel' from U235 or thorium while it is generating energy for power purposes has long been regarded as the great hope for the future in which atomic 'fuel' can be used for electrical generation. The Minister announced that a small experimental breeder pile [called Zephyr] is under construction at Harwell, and will be finished in a few months. A full-scale breeder pile is being designed, and a suitable site is being sought for this. (We have heard it said that construction on this second breeder-reactor will start as soon as a site is found, though no official statement to that effect has yet been made.)

The Minister mentioned Britain's first heavy-water pile which is building at Harwell and will take four years to complete. This is designed to use natural uranium, with heavy water as the moderator. The neutron flow will be more intense than in existing British piles. This pile is essentially a research tool. The Minister stressed that it would not be used to generate power, adding that it would, however, greatly expand the quantities and variety of radioactive isotopes which can be produced for industrial, scientific and medical purposes.

The Minister was very careful not to raise any false hopes and would not hazard a guess as to how many years would elapse before electricity from atomic generators would be available on a significant scale for industrial purposes. He did not see such generators superseding existing types of electric generators in the near future, but said there was no reason why nuclear reactors should not "before very long provide a useful additional source of additional power".

Another aspect of the expansion of Britain's activities in the atomic energy field arose when the Minister of Supply explained why his department required a large supplementary estimate. He spoke of uranium production and said that the process for extracting it as a by-product from South African gold mines had gone ahead more rapidly than had been expected. Large-scale production of uranium is also developing in Australia, and the South Australian Government has just announced plans to build a £A1,000,000 plant at Port Pirie for extracting uranium from ore mined at Radium Hill.

* The U.S. Atomic Energy Commission has one pile in operation at the Arco Proving Ground which produces electricity. But its output is very small—only 250 kilowatts of electric power—and this pile represents only the first step towards harnessing nuclear power on an industrial scale.

ATOMIC AFFAIRS AND THE TRUMAN ADMINISTRATION

The Atomic Age, to use in its popular sense a term which has also gained wide currency in the scientific world in spite of the fact that it gives offence to many individual scientists, is still only in its eighth year. Beginning in 1945, this period coincided almost exactly with the period of the Truman Administration. It was not surprising, therefore, that Mr. Truman, who during his term of office had the ultimate responsibility for decisions made on atomic matters of tremendous consequence, should have devoted a large part of his last message to Congress to reminding the world that atomic weapons make nonsense of the concept that any power can achieve world domination by force of arms. He said that atomic war would destroy the very structure of civilisation, and therefore "such a war is not a possible policy for rational men". The speech also included a direct warning to Stalin that war between the Communist and non-Communist world could bring nothing but ruin for the Soviet régime and homeland, and might also "dig the grave of our own society". This warning was underlined by a passage which is the nearest approach yet made to a categorical admission that the U.S.A. now has the hydrogen bomb. Mr. Truman's exact words here were:

> "The progress of scientific experiment has outrun our expectations. Recently, in the thermo-nuclear tests at Eniwetok, we have entered another stage in the world-shaking development of atomic energy. From now on man moves into a new era of destructive power, capable of creating explosions of a new order of magnitude, dwarfing the mushroom clouds of Hiroshima and Nagasaki."

This brief mention of the H-bomb was embroidered upon later by many commentators, who talked about the Eniwetok explosion being equivalent to that of 3½ million tons of TNT (as against 20,000 tons for the Hiroshima bomb).

Mr. Truman spoke more briefly on atomic energy as an instrument for human betterment. When he said, "We are already making good progress in the constructive use of atomic power; we could do much more if we were free to concentrate on its peaceful uses exclusively", there spoke the voice of a fundamentally optimistic statesman as he recollected the various terrible decisions which the unfolding of the Atomic Age forced upon him. The taking of those decisions, which resulted in the destruction of two Japanese cities and set in motion the H-bomb project, must be considered against the background of American policy designed to avert another total war, and Mr. Truman is entitled to justify his decisions by pointing to the success of that policy during his term of office.

* * * *

Another American who was concerned in high-level policy in the atomic field was the late Senator Vandenberg. The diary and documents he left have now been published in a book (*The Private Papers of Senator Vandenberg*, Gollancz, 25*s*.), which our readers will find interesting for the light it sheds on American-British relations with regard to matters atomic. During the war there was close collaboration between British, American and Canadian atomic scientists. The knowledge and skill of our atomic scientists went into the common pool, and in many respects the atomic-bomb project was as close to being a full partnership between experts from three nations as one can visualise. But in return for all that Britain contributed to the pool, she gained a good deal in return; for example, some top British scientists who worked in the U.S.A. were enabled to gain a picture of the whole atomic bomb project, a picture that was more comprehensive than that obtained by the majority of the American scientists who were involved. This was due to the fact that our scientists were able to move around the different atomic units and see many phases of the work, whereas most of the American scientists were tied to particular atomic units and worked on isolated problems without being able to see how all the pieces of the jigsaw puzzle known as the Manhattan District Project fitted together. The war-time system was generally regarded as a fair if not complete partnership by the British scientists who worked in the U.S.A. But with the end of the war the situation changed, and America showed increasing reluctance to pass on atomic information to Britain. This led to a good deal of resentment in this country. But if we thought we were getting the worst of the bargain, there were plenty of Americans who thought that Britain was actually getting far more than her fair share out of that bargain. How different the same situation looked to British and American eyes is brought out in Vandenberg's papers.

Vandenberg's very active interest in atomic matters began when he became a member of the Joint Congressional Committee on Atomic Energy. Being concerned also with the presentation of American policy on proposals for the international control of atomic energy, he needed to have a clear idea of the extent to which America was committed by her atomic agreements with Britain and Canada. These agreements had been made at the Quebec and Hyde Park conferences, and the details of what Roosevelt and Churchill had agreed upon at these meetings were extremely well-guarded secrets. After the war most Americans probably believed that, if the occasion arose when a decision needed to be taken about the American Services using an atomic bomb made in American factories, then the only country concerned with that decision would be America. According to Vandenberg, however, Churchill and Roosevelt had settled this point, arriving at agreement "of the United States and Britain not to use the atomic bomb against each other; *and not to use it against any other country unless both Britain and the United States agreed*". The fact that Britain was thus placed in the position of being able to veto America's use of the bomb, Vandenberg found "astounding", and indeed he did not rest until the veto power had been cancelled.

Vandenberg also began to ask searching questions about arrangements for the exchange of atomic information between the two war-time partners. At this time the British line was that we were entitled to expect that America would hand over more atomic data, but in America there were many like Vandenberg who thought that the U.S.A. was already being too generous with atomic secrets. He recorded that he found it reassuring to be told by the State Department experts he consulted that the war-time agreements did not provide authority "for giving the British

full information on all phases of atomic energy". (At the same time he was also told that "the British were becoming restless at the failure to obtain a complete exchange of information", which is evidence that Britain had put her case quite clearly to the U.S. State Department, although it might perhaps have been argued more forcefully.)

At this time—the year was 1947—Britain was in considerable need of dollar aid. The Marshall Plan, which would help Britain out of that difficulty, was nearly ready for presentation to Congress. It was now that Vandenberg dropped a hint that failure on the part of Britain to accept alteration of the existing atomic agreements would "have a disastrous effect on congressional consideration of the Marshall Plan". Whether this hint ever reached British ears at that time is not known. With Congress, and with the Administration, it would have carried great weight, for Vandenberg spoke in such matters with the authority belonging to his position as chairman of the Senate Foreign Relations Committee. The undisputed fact is that Britain did drop her claim to the veto, and the Marshall Plan was passed soon after. The new atomic agreement made at a meeting in Washington in January 1948 by the U.S.A., Canada and Britain, also guaranteed to the Americans a larger supply of Belgian uranium ore. (The allocation of uranium ore from the Belgian Congo was another matter which came within the scope of the original Roosevelt-Churchill agreement.)

In 1948, according to Vandenberg's papers, Britain was thus forced to make considerable concessions to the U.S.A. What Britain received in return for those concessions is not at all clear. Vandenberg refers to discussions at the Washington conference which "clarified the general areas of atomic energy information exchange". Out of this may perhaps have come a gain of information which might otherwise not have been given to Britain. But soon afterwards there occurred the curious episode of Dr. Cyril Smith and the fuss about giving facts about plutonium to Britain.

The know-how of plutonium metallurgy was then largely an American monopoly, and the time had arrived when Britain wanted some practical details in connexion with plans for plutonium production in Cumberland. These facts the U.S. Atomic Energy Commission was ready to hand over, and in fact they sent Dr. Cyril Smith to England to discuss this and other matters. The fate of his mission is described at length by Vandenberg, but the key facts can be summarised quite briefly. Apparently the guiding principle at that time was that information could be given to Britain where it was relevant solely to the industrial exploitation of atomic energy; if, on the other hand, it had any connexion with work on atomic weapons then it could not be handed over. Plutonium's metallurgy had some relevance to weapon production, and once the U.S. Secretary for Defence had been convinced that Britain was out to make a plutonium bomb, orders were given to the Atomic Energy Commission to stop Dr. Smith passing on information "if humanly possible". He could not be contacted in London, and it was only after a frantic series of cables and transatlantic telephone calls that he was eventually reached and told that his authorisation to divulge information about plutonium was now cancelled!

Now it is possible to look back on this odd episode of 1948 and to see it as something comic rather than tragic. Britain has moved forward since then; her plutonium plant is operating smoothly, and explosive from it made possible the Monte Bello tests. Britain is today in a stronger position when it comes to bargaining with the U.S.A. for atomic information. Were Vandenberg still alive he might well today be urging the justice of the *British* claims for such information, for towards the end of his life he saw that the fullest co-operation between the U.S.A. and Britain was essential to solve the post-war problems confronting both countries.

Nothing comparable to the Vandenberg disclosures has come from the British side. Mr. Churchill evidently has no immediate intention of giving any more details about war-time atomic agreements, and readers may recall the final words of a reply he gave to a recent parliamentary question on this subject—"I dare say that some day another White Paper will be published giving a fuller account of what happened in 1945 and earlier. But I do not think that the time has come yet."

LINEAR ACCELERATORS

On both sides of the Atlantic, electron linear accelerators are at a stage when more will soon be heard of them. Their use is to give a source of high-energy X-rays, which are produced when the electrons hit a metal target. The main American interest is in the production of nuclear disintegrations by X-rays of the highest energies, and the main effort has gone into a single spectacular project—at Stanford University, California. In Great Britain, the immediate interest has been mainly in energies which, by physicists' standards, are relatively modest; and the British effort, comparable in total extent, has gone into a number of projects, largely on the medical side. There are different reasons for these contrasting types of use; they make sense only if the linear accelerator is considered in relation to other means for the production of high-energy electrons.

In common with the synchrotron, the linear accelerator offers a means by which electrons can be accelerated to high energies without the need for a correspondingly high voltage, and for an insulating column which will withstand this voltage; the latter being the real difficulty with direct (one-stage) acceleration, however the voltage is produced. Beyond a few million volts, insulation becomes rapidly more difficult; and beyond about ten million volts, the problem is insoluble for practical purposes. It is avoided by giving the electrons many small accelerations, instead of a single large one. This is done in the synchrotron by using a magnetic field to constrain the electrons to follow a circular path, and by accelerating them once per revolution. The limit to the energy which can be reached is set by the strength of the magnetic field needed to keep the electrons under control.

In the linear accelerator, on the other hand, the electrons travel in a straight line, and gain energy by 'surf-riding', as it has been said, on the crests of centimetre radio-waves—commonly of about 10-centimetre wavelength. This is in the *travelling-wave* type of accelerator, now chiefly being developed.

The linear accelerator offers two main advantages

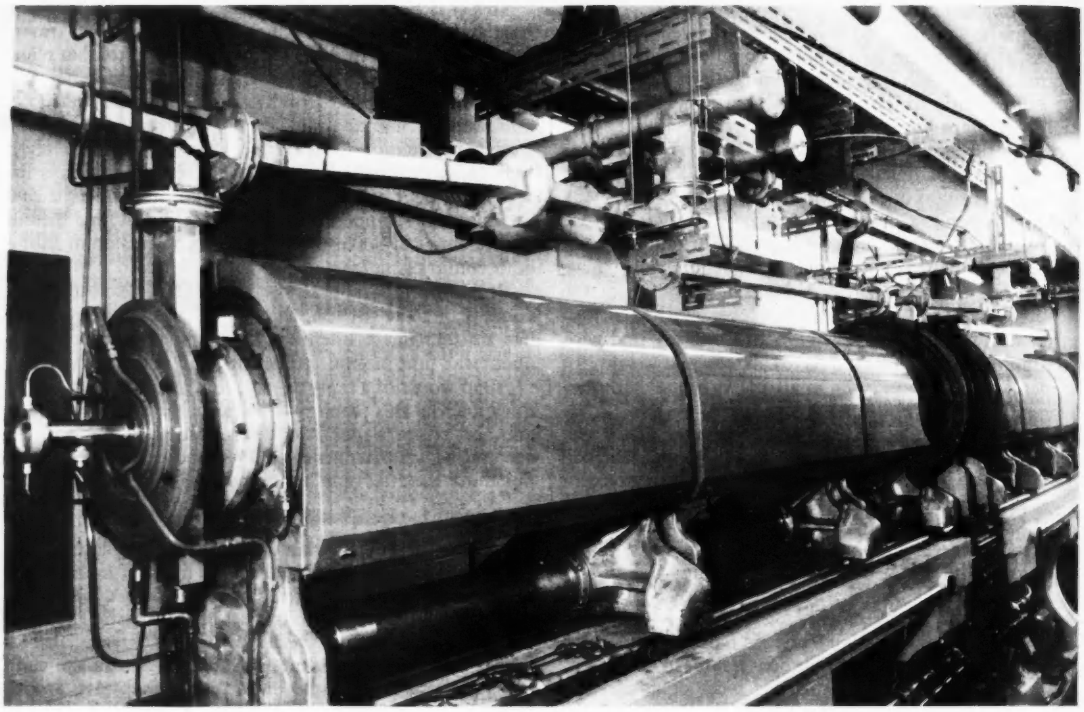


FIG. 1. General view of Harwell's linear accelerator showing its whole 20-ft. length. The target end is at the left. The pumping system, which maintains a high vacuum to minimise collisions of electrons and gas molecules in the waveguides, is connected midway along the accelerator. (*Crown copyright; courtesy, Director of A.E.R.E., Harwell.*)

compared with the synchrotron. One is that many more electrons can be accelerated. More X-rays are therefore produced when the electrons hit a target—and the dosage rate can thus be increased in medical use. This advantage does not depend on the attainment of any particularly high energy; it begins to be felt at any energy greater than the million or two volts attainable with already existing types of generator. It applies also in other uses: for example, it applies when the X-rays which the instrument can create are used in turn to produce neutrons. It is this advantage, that more electrons can be accelerated, that British workers have so far mainly exploited.

The second advantage is a matter of arithmetic. The cost of any 'whirligig' type of accelerator rises steeply as the energy is increased. This is because of the large magnets that are needed. The cost of a linear accelerator, if not exactly linear, rises at a comparatively modest rate in relation to energy. There is also the practical advantage that the linear accelerator is a comparatively untemperamental kind of machine; it works commonly at the first attempt.

For a 'travelling wave' accelerator to be practical, the first requirement is for a high-power source of radio-waves of centimetre wavelength. This was met by the development of the cavity magnetron during the war for use in radar. Secondly, if the electrons are to surf-ride while gaining energy, it is necessary that the speed at which the radio-waves travel should be controllable. In its radar use, the output of the magnetron is fed into a hollow metal waveguide; and by inserting corrugations into the waveguide, the velocity of the waves can be controlled. The only further requirements—in principle—are that means should be provided for injecting a stream of relatively low-energy electrons into the waveguide, and that there should be some method of focusing—in practice magnetic—during the early stages of acceleration.

Work on the problem was begun by D. W. Fry and his colleagues at the Telecommunications Research Establishment, Great Malvern, in 1946. By November-December of that year, the practicability of the method had been established. In 1948, electrons were accelerated to 3·2 million electron-volts energy (3·2 MeV) in a corrugated guide of 2 metres length; this was to be the first section of a 20 MeV accelerator, which was not completed. During the same period, it was realised that output could be increased by feeding back surplus radio-energy from the far end of the guide to the beginning of it. This is done through a subsidiary metal waveguide, connected to a device known as the 'rat race' in which the surplus power and the input power are added together. This device has been included in all later British accelerators.

For medical use, there is an 8 MeV machine, which has

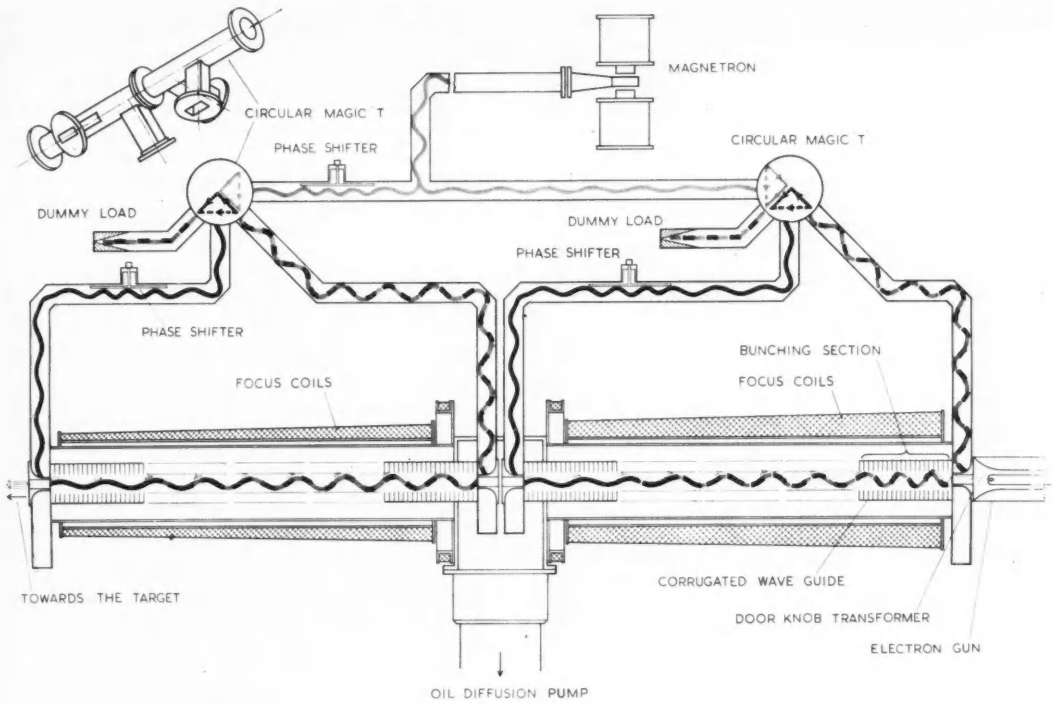


FIG. 2. This diagram conveys the principle of the system for accelerating electrons in Harwell's 15 MeV linear accelerator. The magnetron generates pulses of radio-frequency waves (of 10-centimetre wavelength), which are delivered through waveguides to one end of the two sets of corrugated waveguides in the accelerating unit. There are six corrugated waveguides in all, each 3 ft. in length and joined end to end. In the first section (the 'bunching' section) of the corrugated waveguide the electrons coming from the electron gun are bunched into groups: these electron pulses are synchronised with the radio-wave pulses, as the same modulator unit pulses both magnetron and electron gun. The bunches of electrons 'surf-ride' on the crests of the travelling radio-waves, gaining in speed the farther they travel: they finally leave the accelerator with a velocity about 99·95% of that of light, and a mass about thirty times greater than their original mass on entry. Focusing coils around the corrugated waveguides keep the electrons from wandering outside the accelerating field; they are visible in this month's cover picture.

been built by Metropolitan-Vickers for the Medical Research Council and has passed its factory tests; and five 4 MeV machines which are being built, three by Metropolitan-Vickers and two by Mullard Ltd. on behalf of Philips, for the Ministry of Health. These are distinct designs with different mechanical arrangements. In the M.R.C. machine, the accelerator is fixed; but the output from it can be rotated in a vertical plane, and the floor beneath the output beam will be raised or lowered. It is to be used at the Hammersmith Hospital. In the five Ministry of Health machines, the whole accelerator unit will be supported by a gantry mounting, so that the machine can be moved to any position in an arc round the patient. These machines are destined respectively for the Holt Christie Hospital, Manchester; the Royal Infirmary, Edinburgh; the Mount Vernon Hospital, Northwood; the Royal Victoria Hospital, Newcastle; and the Radium Institute, Liverpool.

It is natural to ask what benefit may be expected from these machines in the treatment of cancer. The use of higher energies will not alter the balance of damage as between cancer and normal cells. What it will do is to alter the balance between the dosage which can be given at a depth and the degree of skin-burn at the surface. This is an important gain both for those who receive such treatments, and for those who give them. In some cases it will enable treatment to be more thorough, and therefore more effective; in others, less unpleasant; and in others again it may make X-ray treatment worth while, where it would not otherwise have been. Finally, compared with the synchrotron, the required dosage can be given in a few minutes, compared with perhaps half an hour, so that more use can be obtained from the equipment.

As an instrument for use in nuclear physics, the original 3·2 MeV machine was rebuilt by Mullard and installed at Harwell. It has since been replaced by a 15 MeV machine, built by Mullard, which is being used to provide neutron pulses—produced by irradiating a uranium target with X-rays—of energies which can be accurately measured.

A second 15 MeV machine is to be built for St. Bartholomew's Hospital as a medical instrument.

Meanwhile, the construction of a travelling-wave linear accelerator of enormously higher energy has been proceeding at Stanford University. The project raised further problems both on the radio side and in precision of construction. With an accelerator built in many sections, it is necessary to provide a succession of radio-oscillators, and that their frequencies shall be kept exactly in step. Since the matching-up of any large number of magnetrons is all but impossible, this suggested the use of a single master-oscillator, driving a number of power-amplifiers with the necessary high output at centimetre wavelengths. The late Dr. William Hansen, formerly director of the Stanford Microwave Laboratory, and his associate and successor, Dr. E. L. Ginzton, undertook the development for this purpose of the 'Klystron' type of valve, used in radar receivers. Before his death in 1949, Hansen had designed a Klystron amplifier to work at 10-centimetre wavelength which could handle an input power in short pulses of up to 100 megawatts. This was a really major undertaking. Results have been good enough to make possible the operation of a linear accelerator which, in December of last year, produced electrons of 350 MeV energy. The final design-figure (with further sections added) is 1000 MeV. At this figure, the linear accelerator will have established its claim to be the best means for the production of electrons, and so of X-rays of the highest energies for the study of nuclear disintegrations. The Cavendish Laboratory at Cambridge has also preliminary plans for a travelling-wave accelerator which will produce electrons of very high energy.

(Readers who want a detailed account of the principles of the linear electron accelerators should consult the contribution by D. W. Fry and W. Walkinshaw to the Physical Society's *Reports on the Progress in Physics*, Vol. 12.) This month's cover picture was taken by Walter Nurnberg when the 15 MeV accelerator was assembled in the Mullard Laboratories, prior to its installation at Harwell.

KRILIUM FOR BRITISH GARDENS

Among the synthetic soil conditioners which made news in 1952, outstanding was the proprietary material known as Krilium. Readers will recall the long note which appeared in DISCOVERY (February 1952, pp. 39–42) about its action in improving the physical conditions of soil by giving it a good crumb structure, which results in a better balance between water content and air content in the soil, and the promotion of plant growth. On the one hand, its action is analogous to that of, say, lime, in causing aggregation of clay particles into larger particles; this effect depends on the dissociation of Krilium into poly-anions—that is, large ions carrying many electric charges—which bring about flocculation of clay more effectively than do the calcium ions, with a double electric charge apiece, produced when lime dissolves in soil water. On the other hand, its action can be compared, and more closely compared, to that of the natural constituents of humus known as *polyuronides*; poly-anions from substances in this class play a big part in ensuring that a particular soil has desirable physical properties. Within this context Krilium can thus be regarded as a synthetic substitute for humus.

Krilium, it should be noted, is a generic term. The original Krilium marketed in the U.S.A. contained a sodium salt of polyacrylic acid, commonly called *CRD–189* in the research papers describing the results of its field trials. The Krilium now being made in Britain (and which any reader can obtain through ordinary retail horticultural suppliers) is based on an entirely different material—a calcium salt of a copolymer of vinyl acetate and maleic acid, which is called *CRD–186* in the research literature.

* * * *

Last year trials of CRD–189 were carried out in Britain under the auspices of the Agricultural Research Council. This organisation has now issued a brief statement about these preliminary experiments, the results of which justify the following conclusions:

1. Improvement in structure after treatment was apparent in many of the soils tested.
2. The uptake by plants of major and minor nutrients was not adversely affected.
3. The activity of soil micro-organisms was normal.
4. No conclusive evidence was obtained that the application of Krilium caused any significant increases in crop yields of field or of glasshouse crops, though in certain cases increased yields were recorded. Much more experimental evidence on the best method of incorporation, degree of aggregation and persistence of structure of treated soils, and the relation of these to crop yields is required before any definite conclusion can be reached.

The A.R.C. will this year continue its experiments with CRD–189, and it is beginning trials of CRD–186, which is more easily incorporated into British soils, which on the whole tend to be moister during the growing season than American soils.

It was work done by J. H. Quastel (now a professor at McGill University, Montreal) and D. M. Webley at Rothamsted Experimental Station on the soil-conditioning properties of natural polyuronides which put the chemical industry on the road which eventually led to the manufacture of synthetic soil conditioners. There are many points about the practical use of the latter which can only be settled by field trials carried out over a longish period; for example, the economics of their horticultural and agricultural use requires the knowledge of how long soil conditioners exert these beneficial effects in the soil. The full potentialities of synthetic soil conditioners cannot be assessed for some time, but it is quite clear that their large-scale exploitation, should that materialise in the future, would revolutionise horticultural practice and market gardening. What their impact on arable farming might be is far less certain. But Prof. Quastel* is quite justified in saying that "The advent of these conditioners heralds a new phase in agricultural science, of equal importance perhaps with that brought about by the first application of the artificial fertilisers."

* This comment is made in an article on Krilium and Synthetic Soil Conditioners, published in *Nature*, Jan. 3, 1953, p. 7; this is a useful summary of the researches done between 1947 and 1952, and contains a valuable set of references.

ADRENAL STEROIDS AND ACTH

PROF. F. G. YOUNG F.R.S.
Sir William Dunn Professor of Biochemistry, University of Cambridge

It is now a commonplace fact that the health, and even the survival, of the human body depends on the proper functioning of glands weighing only a comparatively few grams apiece; nevertheless, such a possibility was hard to accept, let alone to conceive, when the investigation of the endocrine, or ductless glands, began in earnest a hundred years or so ago. These glands were called ductless glands because they possessed no obvious duct for the liberation of secretions (in contrast to the salivary glands, for instance), and although the possible function of the ductless glands evoked boundless speculation, there was no significant experimental investigation in progress upon it a hundred years ago. But in 1855 Thomas Addison of Guy's Hospital, London, described an illness which now bears his name, the development of which he connected with a diseased condition, or disappearance of the adrenal glands (or suprarenal capsules, as they are sometimes called), two small ductless glands lying above the kidneys in the human being.

Although Addison's important observations provoked investigation of the possibility that experimental removal of the adrenal glands from an animal would cause death, this fact was not unequivocally demonstrated until over fifty years later, partly because of the surgical difficulties involved in the removal of these small organs.

THE CONCEPT OF A HORMONE

In the meantime research upon other ductless glands was progressing, and thirty years ago it was known that a number of them manufacture specific chemical substances which they secrete directly into the bloodstream, to be borne to other parts of the body to fulfil some physiological function. Such chemical messengers were named *hormones* by Bayliss and Starling in 1902, and as examples we may mention thyroxine* secreted by the thyroid gland, insulin produced by the islet tissue of the pancreas, and the sex hormones liberated by the gonads and responsible for the development of the secondary sex characters. Although by 1922 it was possible to say with certainty that these, and certain other hormones, existed, the function of the adrenal glands remained an unsolved mystery, although it was known by this time that experimental removal of these glands was invariably fatal.

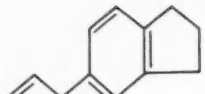
True, in 1894, it had been found by Oliver and Schäfer that the adrenal glands contained a substance of extraordinary ability to raise the blood pressure and accelerate the heart rate, but this substance, named adrenaline or epinephrine, proved to be incapable of preventing the death of adrenalectomised animals (i.e. animals from which adrenals had been removed). Moreover, it was shown that adrenaline is produced by the inner portion of the adrenal gland (the adrenal *medulla*), while removal of the outer portion (the adrenal *cortex*) but not of the medulla, was fatal.

ISOLATION AND STRUCTURE OF ADRENAL STEROIDS

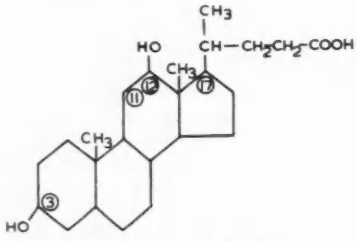
It was not until 1929 that Swingle and Pfiffner in the U.S.A. obtained extracts of the adrenal glands which could prolong virtually indefinitely the life of adrenalectomised animals and of patients with Addison's disease, and it is of interest to inquire why these workers succeeded where others had so signally failed. One reason undoubtedly lies in the fact that earlier investigators had largely used *aqueous* solutions for extracting hormones from glands, while Swingle and Pfiffner used *fatty* solvents. Now it may seem logical to argue that since a hormone is carried in the bloodstream—an aqueous medium—the hormone must be water-soluble, and would therefore best be extracted from the parent gland by aqueous solvents. But the adrenal cortex contains much fatty material, and we now know that although the hormones concerned are soluble in water to some extent, they dissolve most readily in fatty solvents, especially during the first stages of extraction from the gland. Furthermore, Swingle and Pfiffner filtered their extracts through permutite to remove basic adrenaline and its decomposition products, which were toxic to adrenalectomised animals. Incidentally this work provided an early example of the use of ion-exchange substances in biology. In order to keep their adrenalectomised animals alive they were not afraid to administer what then appeared to be unreasonably large doses of adrenal extract. Since we now know that the normal rate of secretion of the adrenal glands of an animal such as the dog is so high that the stored extractable hormone would be exhausted in about 10 seconds, it is clear that the adrenal glands store little preformed hormone, at least in an extractable state, and that many workers must have failed because they administered much too little extract.

For these and other reasons Swingle and Pfiffner succeeded where others had failed, but the difficulties of isolating substances in a pure state from the extracts which they prepared were such that others stepped into the picture at this stage of the investigation, in particular Reichstein in Switzerland, and Kendall in the U.S.A., together with many of their colleagues. Now in 1929 it was generally accepted that each ductless gland secreted one hormone. But from 1935 onwards, Reichstein, Kendall and others, as the result of working up extracts from many tons of adrenal glands, isolated seven crystalline substances which were active in keeping adrenalectomised animals alive and in good condition. Moreover, the method of preparing these substances involved the use of differential solution in aqueous and fatty solvents, one group of substances dissolving more readily than the others in the fatty solvents from which they could later be crystallised, while others

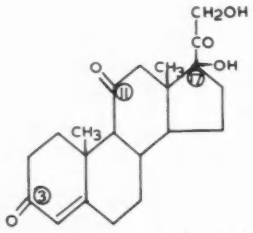
* Very recent research suggests the possibility that the thyroid gland also produces tri-iodothyronine; that is, thyroxine minus one iodine atom, and a substance more active than thyroxine!



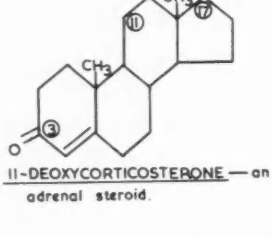
CYCLOPENTENOPHENANTHRENE :— the hydrocarbon of which sterols and steroids are derivatives.



DEOXYCHOLIC ACID —a steroid from bile.

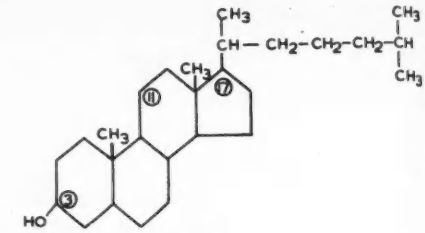


CORTISONE—an adrenal steroid.

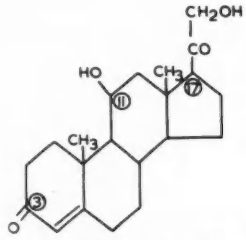


11-DEOXYCORTICOSTERONE—an adrenal steroid.

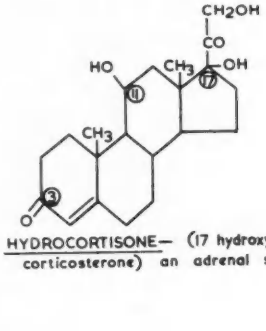
HECOGENIN—a plant steroid



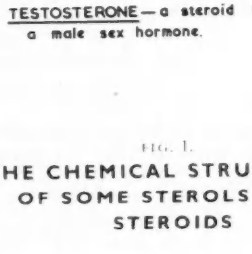
CHOLESTEROL— a sterol.



CORTICOSTERONE—an adrenal steroid.



HYDROCORTISONE— (17 hydroxy corticosterone) an adrenal steroid.



TESTOSTERONE—a steroid which is a male sex hormone.

FIG. 1.

THE CHEMICAL STRUCTURES OF SOME STEROLS AND STEROIDS

dissolved more easily in aqueous-alcoholic solution. Later still, after the more water-soluble substances had also been crystallised out, there remained an uncrystallisable water-soluble syrup (called the "amorphous fraction") which was found to be even more active than any of the crystalline materials in keeping adrenalectomised animals alive. It was therefore difficult to decide whether any of the isolated substances could be regarded as *the* hormone of the adrenal cortex.

In 1937 Reichstein made the important discovery that the crystalline substances isolated from the adrenal cortex were close relations of cholesterol, a fatty substance which is present throughout the animal body, and which is particularly abundant in the adrenal cortex.

Cholesterol is an example of a class of chemical substances known as *sterols*, which are widely distributed in nature. Even before the chemical structure of the sterols was known it was clear that they were close chemical relatives of the bile acids, which are fatty substances present in the bile. Moreover, it had been found in the early 1930s that the sex hormones were also chemically related to cholesterol.

Fig. 1 illustrates the closeness with which the molecular structure of cholesterol and deoxycholic acid resembles that of the adrenal steroids, and reveals why it has been possible for cholesterol and bile acids to be transformed into adrenal steroids on an industrial scale. The first adrenal steroid to be thus produced was 11-deoxycorticosterone from cholesterol in 1937. Recently cortisone has been produced on a large scale, and relatively cheaply, from deoxycholic acid, and although the complete chemical synthesis of this and other adrenal steroids is now possible, completely synthetic methods of production are unlikely to oust for some time to come those based on natural products.

THE ACTION OF CORTISONE

Tests involving the survival of adrenalectomised animals are costly and difficult to carry out, and other methods for testing adrenal steroids were early sought. Of the many that have been developed, only one will be mentioned, that of D. J. Ingle, who measured the ability of an adrenal steroid to prevent undue fatigue in the leg muscle of an adrenalectomised rat when it was electrically stimulated to do work. This "Ingle work-test", as it was called, yielded comparative results quite different from those derived from survival tests, that is tests involving the maintenance of an adrenalectomised animal in good health. Thus corticosterone, cortisone and hydrocortisone were all much less active than either 11-deoxycorticosterone or the amorphous fraction in survival tests, while conversely the members of the first group were much more active than the latter in the Ingle work-test. In general, those adrenal steroids with an oxygen atom or hydroxyl group at position 11 were much more active in the Ingle work-test than those without such an oxygen atom or hydroxyl group. The high activity of cortisone in the Ingle test, compared with its very low activity in survival tests, puzzled many people and kept alive interest in this substance. Nevertheless, until 1948, much less attention was paid to cortisone than to corticosterone and some other adrenal steroids, since these were so much more active in survival tests.

But in 1948 Philip Hench demonstrated the dramatic effects of the administration of cortisone in alleviating rheumatoid arthritis in human beings. This discovery resulted from Hench's investigation of the temporary amelioration of rheumatoid arthritis which often occurs during pregnancy. Since there is evidence of increased activity of the adrenal cortex in pregnancy and since Hench and Kendall, both working at the Mayo Clinic in the U.S.A., had a supply of cortisone available, this substance was administered to arthritic patients, with outstanding results which were widely confirmed. Subsequently, it was found that hydrocortisone had a similar action, but not corticosterone or 11-deoxycorticosterone; it appears that the presence of a hydroxyl group at position 17 is necessary for this action (see Fig. 1).

Cortisone was later shown to exert a favourable effect on a wide range of diseases, and naturally much research has been carried out to elucidate the nature of this action, though so far without conclusive result. In general terms it appears that cortisone and hydrocortisone are able to protect the tissues of the body against undesirable stimuli, perhaps by reducing the response of the tissue to the stimulus; such a reduction may be associated with the depression of protein synthesis which follows the administration of these steroids. One puzzling feature is that there is no clear evidence of a deficiency of cortisone or of hydrocortisone in rheumatoid arthritis or in other conditions which are favourably influenced by these steroids. Much research remains to be done in this connexion.

NATURE OF THE SECRETIONS OF THE ADRENAL CORTEX

It is only recently that analysis of the blood flowing from the adrenal gland has permitted the identification of the steroids actually secreted into the bloodstream. It now appears probable that there are at least three substances liberated: corticosterone, hydrocortisone and an unidentified steroid, which is probably also present in the amorphous fraction of adrenal extracts. Strangely enough the major secretory products of the adrenal cortex do not include either cortisone or 11-deoxycorticosterone, although these substances may possibly be secreted in small amounts. It is perhaps unlucky that the two steroids so far most easily available by artificial production, namely cortisone and 11-deoxycorticosterone, and therefore more investigated experimentally than the others, are apparently not present in any large amount among the steroids secreted by the adrenal glands, and so they hardly qualify for the description 'hormone' It may be that these two substances, which are present in adrenal extracts, represent stages in the transformation in the gland of cholesterol to the secreted adrenal steroids. It is certain now that there is more than one hormone of the adrenal cortex, and that the three or more secreted substances present a combination of physiological actions which are possessed by no single substance present in the gland.

ACTH

In 1927 Philip Smith showed that when the pituitary gland is removed from a rat, the cortex of the adrenal glands atrophy, but that this atrophy could be prevented

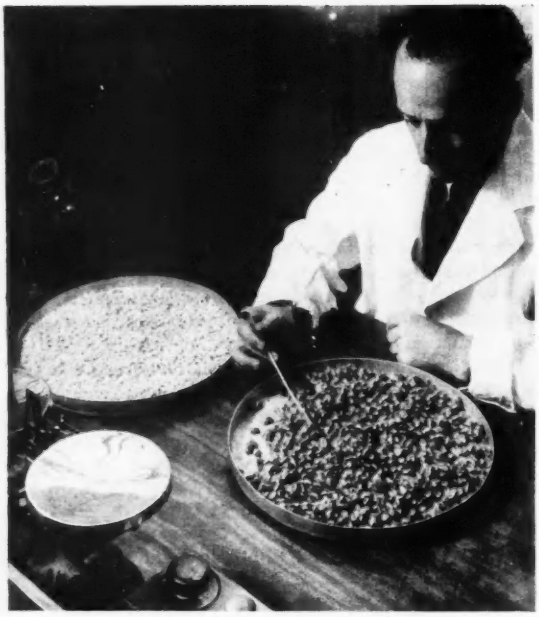


FIG. 2. British production of ACTH and cortisone is rapidly expanding. This photo shows dried pig pituitary glands from which ACTH is prepared at a Scottish factory.
(*Courtesy, Organon Laboratories Ltd.*)

or cured by the administration of material from the anterior lobe of the pituitary gland. Thus was born pituitary ACTH (the four letters come from the term adrenocortico-tropic hormone), a hormone which is known to stimulate the secretion by the adrenal cortex of the steroid hormones, and which therefore acts like corticosterone or hydrocortisone in any disease which does not involve loss of adrenal cortical function. ACTH itself is not a steroid, but is possibly a peptide, a substance which can be formed by the partial hydrolysis of a protein. It has not yet been isolated in a state of purity, and its structure has therefore not yet been determined, let alone its synthesis achieved.

In acting on the adrenal cortex, ACTH apparently stimulates the conversion of the cholesterol stored in the gland into the adrenal steroids, which are then secreted. The presence of large amounts of the precursor cholesterol in the adrenal cortex may account for the fact that only a small amount of preformed adrenal steroid is stored there, since the transformation of cholesterol to steroid can take place rapidly and in large amount under the stimulating influence of ACTH.

THE ARTIFICIAL PRODUCTION OF CORTISONE

The commercial production in the U.S.A. of cortisone from bile acids, obtained from animal bile, represented a great achievement in itself, and the rapid expansion of this industry necessitated by Hench's unexpected discovery was a remarkable feat. Meanwhile other natural starting materials suitable for the production of cortisone have been sought. In the conversion of sterols and certain bile acids to cortisone or hydrocortisone one of the difficult steps is the introduction of the oxygen atom or hydroxyl group at position 11. This process is facilitated if an oxygen atom or hydroxyl group is present at position 12, as in deoxycholic acid, but supplies of such bile acids are limited, and in any case the removal of the extra carbon atoms in the side chain at position 17 represents a big difficulty. Some plant steroids with suitable side chains at position 17 possess an oxygen atom at position 12, of which hecogenin is one example (Fig. 1). Recently it has been recognised in Great Britain that hecogenin can be extracted from the waste products obtained in the preparation of fibres from sisal plants, and it is possible that sisal waste may prove to be a fruitful source of cortisone and hydrocortisone in the future.

An interesting manner of introducing an oxygen atom into steroids at position 11 is by perfusion of them through surviving adrenal glands, and this method has already been used on a commercial scale in the U.S.A. It has also been found possible to introduce an oxygen atom into position 11 of steroids by taking advantage of the metabolic activities of micro-organisms. Two different types of fungi have been used in this work, which is a novel example of microbes in the service of man, and which promises to be of considerable industrial significance.

* * * *

It is a long path from Addison's first observations a hundred years ago, to the multiplicity of facts available at the present day, but even with all the research carried out in the past years we are still unable to say either what is the function of the adrenal cortex or precisely which steroids constitute its hormones. But in cortisone the biochemist, physiologist and physician have a key to new and entirely unexpected fields of conquest, while to the chemist the examination and synthesis of the apparently endless types of steroid which exist in nature, and the interconversion of them, will provide material for research for some years yet.

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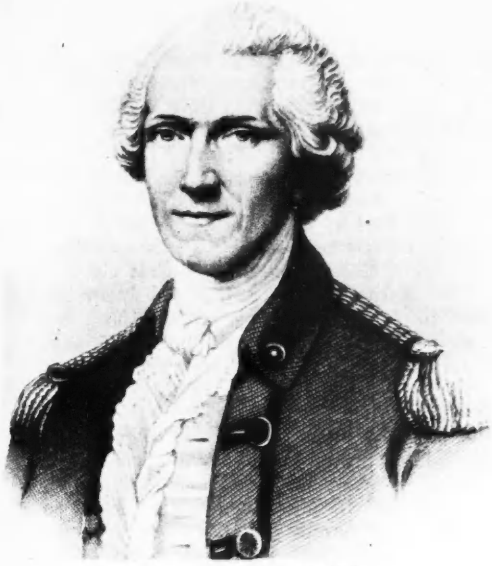

Rumford at the age of 30.

THE INSUFFERABLE GENIUS

COUNT RUMFORD (1753–1814)

EGON LARSEN

The bicentenary of Rumford's birth will serve as a cue to revive his memory in Germany as well as in this country; the U.S.A. and France will also join in the celebrations, for it was in America that he was born—on March 26, 1753—and in France that he spent his last years.

Many tributes to his achievements will no doubt be paid during the course of this year, but if these lack something of the warmth and spontaneity customary on such occasions this would not be altogether surprising; for posterity seems to bear some grudge towards Rumford, probably because of the fact that throughout his life he was an insufferable genius with a strange knack of making personal enemies of those who should have been his friends.

Psychologists may find the clue to his peculiar attitude towards his fellow men—to say nothing about the women in his life—in his own words. "If the death of my father had not, contrary to the order of Nature, preceded that of my grandfather, who gave all his property to my uncle, his second son, I should have lived and died an American husbandman. This was a circumstance purely accidental, which, while I was still an infant, decided my destiny in attracting my attention to objects of Science."

What the death of Benjamin Thompson's father had in fact done to the boy was to deprive him of what he felt was his own by birthright—the family's little farm at North Woburn, near Boston, Mass., and the sense of security that went with it. Worse still, his mother married again, bestowing on a stranger the affection which the child claimed for himself alone.

His stepfather apprenticed him to a general merchant, but he was less interested in serving the shop's customers over the counter than in reading 'philosophical' books under it. His teachers, after working hours, were a preacher and a young engineer. "Before the age of 14", he recalled, "I was able to calculate and trace rightly the elements of a solar eclipse. My computation was correct within four seconds. . . . My thirst for knowledge became inextinguishable."

The repeal of the Stamp Act in 1766 was an occasion for general rejoicing in New England, and young Thompson volunteered to arrange a special firework display. But his preparations for the celebrations brought his apprenticeship to a premature end, for he blew himself up with his fireworks. When he had recovered from his injuries he began to attend courses in 'experimental philosophy' at Harvard College, walking all the way from Woburn to Cambridge with his engineer friend, and building his own apparatus to repeat at home the experiments he had seen. For a short time he lived in the house of a doctor, assisting him and studying medicine. Eventually, at the age of 18, he took up teaching as an itinerant schoolmaster.

It was in this capacity that Benjamin Thompson moved into the house of a well-to-do parson at Concord, New Hampshire. The town had formerly been called Rumford —a phonetic form of Romford, the Essex brewery town from whence the first settlers had come. It had belonged to Massachusetts, but was transferred to New Hampshire after the amicable settlement of a dispute between the two provinces, and renamed Concord to mark the event.

Here, Thompson's fortune took a decisive turn. He married the parson's daughter, a rich widow fifteen years older than he, and thus the poor schoolmaster became a gentleman of independent means.

One day the Governor of New Hampshire saw this young man on horseback, cutting a magnificent figure, and offered him on the spot a commission as a major—which meant by-passing a number of experienced officers. But Thompson was not expected to appear on the barrack square: he acted as a British secret agent among the rebellious Americans. Twice he was summoned before the local People's Committee and charged with "being unfriendly to the cause of Liberty", but there was no real evidence against him. Eventually, however, things became

too hot for him, and he made his escape, joining the British troops at Boston. When General Washington drove them back to their ships, Thompson sailed with them to England.

He submitted a detailed report of the events and conditions in America to Lord Germain, with the result that the latter appointed him Under-Secretary of State in his Colonial Office, with the job of organising transport and supplies for the troops in America. He carried out his task with great efficiency; he was also able to take advantage of his position and indulge his scientific curiosity in a series of large-scale experiments with naval cannon, in which he measured the velocity of missiles and the recoil under various circumstances.

Another line of research which interested him was concerned with the cohesive force of various bodies; for these experiments he used his leisure time while taking the waters at Bath. The outcome was his first essay, which he submitted to Sir Joseph Banks, the President of the Royal Society, with whom he remained on intimate terms throughout his life. It was largely due to Banks's influence that he was elected an F.R.S. in 1779.

SOLDIERS AND BEGGARS INTO CITIZENS

After another short spell of service in America, Thompson was pensioned off at the close of the war, and went to the Continent in search of military adventure. It was an old lady in Vienna, the widow of an Austrian general, who "cured me in season of this martial folly . . . and opened my eyes to other kinds of glory than that of victory in battle", as he confessed later.

He asked King George III for permission to accept an offer by the Bavarian Elector, who wanted Thompson to study the possibility of extensive reforms in his country. The King granted permission, and at the same time knighted Thompson in appreciation of his services. Sir Benjamin spent four years in Munich, carrying out investigations into the muddle which passed for administration in Bavaria in 1788. He came to the conclusion that reforms would have to start within the army to be effective, and in a memorandum submitted to the Elector he suggested extremely bold and unusual measures.

So impressed was the Elector with Thompson's conclusions that he gave him all the authority he required to enable him to put his own recommendations into effect. At one fell swoop he was appointed Minister of War, Minister of Police, Major-General, Chamberlain of the Court and State Councillor.

The central theme in his programme of reform was "to unite the interest of the soldier with the interest of civil society, and to render the military force . . . subservient to the public good". His first step was to make the garrisons throughout the country permanent, so that the soldiers could stay near their homes. They and their wives and children were encouraged to attend schools. Then he made a special drive to eliminate as far as possible the long periods of idleness which had hitherto been accepted as inseparable from the soldier's way of life. Road-making and the drainage of marshes were two kinds of work for which Thompson, with his system of extra pay, encouraged the troops to volunteer; similarly he was able to induce them to work in local factories.

The problems of feeding large numbers of people engaged his attention, with the result that he became one of the first scientific dieticians and experts on fuel economy. Every military garrison had to lay out its own vegetable garden, and here Thompson insisted on the value of crop rotation. He was also able to restore the potato to favour. This vegetable had fallen into disrepute in the war between Prussia and Austria, when the armies were forced to live almost entirely on potatoes; it was nicknamed the "potato war". Under Thompson's régime every private soldier was given a potato patch of 360 square feet and free seed to plant it with. As a result of his efforts the potato gradually became a staple food in Bavaria, and from there its popularity spread throughout Germany.

THE "RUMFORD STOVE"

After putting Bavaria's soldiery to work, he tackled another difficult problem of getting Munich's beggars off the streets. The solution was found more swiftly than anyone expected. He offered the beggars decent accommodation, food, warmth and paid work in a 'military workhouse' equipped with workshops and tools for many trades. Surprisingly, they liked this new way of life right from the start, and remained deeply grateful to their "benefactor", as they called Thompson.

For this workhouse he had designed a kitchen range which became the prototype of the nineteenth-century domestic hearth. Faced with the necessity of feeding great masses of people economically, he had carried out many experiments, standardising and measuring the amount of fuel used for various dishes, and timing the process of cooking. His kitchen-range—probably the first domestic appliance designed by a scientist so as to combine fuel economy and labour-saving features—was a closed stove (nearly all the cooking was previously done on open fires) with a number of separate fireplaces, one for each pot or pan. Thompson even invented the beggar's menu, the main dish in which was a *potage* of potatoes, barley, peas and bread—that is known to this day in Germany under the name of Rumford soup.

After the death of the German Emperor in 1792, there was a short interregnum in which the Bavarian Elector acted as the vice-regent, and he used this opportunity to create Sir Benjamin Thompson an Imperial Count. Thompson chose as his new name the old one of the town where his good fortune had begun—Rumford.

As was to be expected, his successes and his autocratic ways combined together to increase his unpopularity among the Bavarian courtiers and dignitaries. The Munich town councillors even petitioned the Elector to remove Rumford from his numerous offices. Weary of these struggles, he travelled to England to arrange for the publication of a number of his scientific essays, and to meet his daughter, whom he had not seen since his hasty departure from New England. Her diary offers an interesting private portrait of her father as a self-centred, hard-headed, fussy but fascinating man. Another portrait has been drawn by the Swiss scientist, Professor Pictet, who shows us Rumford as a reformer who well understood the terrible warning of the French Revolution, but nevertheless believed that the Chinese system of benevolent

dictatorship by a few wise men for the common good was the best possible régime.

He often thought of returning to America, and prepared the ground by a donation of $5000 to the American Academy of Arts and Sciences for annual awards of "Rumford Medals" to the authors of the most important discoveries or improvements on heat and light. He gave to the Royal Society £1000 to stimulate such work in Britain.

What made Rumford's name first popular in England was the "Rumford Roaster", which he introduced into the London Foundling Hospital. It consisted of an ingenious kitchen oven, with hot-air pipes to control the browning of the joint and steam boxes for boiling. The fuel saving achieved by the roaster, as compared with the open fireplace which had been used before, was said to be nearly 90%.

Lord Palmerston asked Rumford to advise him about the smoke nuisance in his house in Hanover Square. The result was that Rumford designed a new type of fireplace to supersede the wasteful, inefficient and injurious large open fires then generally in use. It was soon indispensable in London's fashionable society. Rumford had 150 of them produced and installed within a few weeks, with the help of a Chelsea pottery, the King's ironmonger and a firm of bricklayers, yet he refused any personal profit from his invention and published its specifications for all to copy.

The "Rumford Stove", as it was called, marked the first phase in the battle against England's waste of fuel. Rumford reduced the width of the chimney substantially, determined the most effective angle between the sides and the back of the fireplace at 135 , and the width of the back at only one-third of that of the front opening so as to radiate the heat into the room. The back and sides were carried up perpendicularly until they joined the 'breast', while the throat of the chimney was only about 4 inches wide. It can be seen from these points that the Rumford Stove is still essentially identical with present-day fireplaces. But Rumford looked beyond the fireplace era. "I am sanguine enough", he wrote, "to expect that the time will come when open fires will disappear. . . . Genial warmth can certainly be kept up, and perfect ventilation effected much better without them than with them." We could do much worse than listen to Rumford's words, written over 150 years ago, condemning the "folly of sitting in a room which has a large blazing fire roasting one side of the body, while blasts of cold air are coursing the apartment".

WHAT IS HEAT?

One of Rumford's essays in 1796 suggested the introduction into England of measures similar to those with which he had abolished beggary in Munich, and the creation of a "Society for Bettering the Condition and Increasing the Comforts of the Poor". The response was gratifying and the new Society was formed by a group of distinguished people, among them William Wilberforce, the Earl of Winchelsea, and Sir Thomas Bernard, the philanthropist. Rumford intended that the "primary object" of the Society should be the feeding and employment of the poor, while a "secondary object", to be carried out later, was to be the "formation of a grand repository of all kinds of useful mechanical inventions".

A Gillray cartoon of Rumford and his 'Stove'.

In the midst of these activities, Rumford was suddenly called back to Munich, which was in danger of being fought over by two hostile armies, the French and the Austrian. The Elector, instead of entrusting a Bavarian statesman with the job, preferred to recall Rumford to assume supreme power and deal with the emergency while he himself fled to Saxony. Again Rumford succeeded, preventing either army from entering the capital.

He decided to stay on in Munich, mainly in order to carry out experiments he had long had in his mind. Munich's new arsenal, which he had built, afforded him all the facilities he needed for this research into the nature of heat.

The 'caloric' theory—postulating the existence of an elastic fluid in every material body, a fluid which was held to ooze out in the form of heat as a result of friction, percussion or compression—was still the dominant theory among natural philosophers. Rumford set out to kill it.

During the boring of a cannon, at which two horses were used to turn the cylindrical gun-barrel while a blunt tool was pressed into it, he fixed a large basin of cold water so that it would take up the heat from the cylinder and the metal dust and chips. "It would be difficult to describe the surprise of the bystanders on seeing a large quantity of cold water heated and actually made to boil without fire",

he wrote in his paper on "An Experimental Inquiry concerning the Source of Heat Excited by Friction", which was read to the Royal Society in 1798. At the end of one hour, after 1920 revolutions, the temperature had risen by 47 F.; after 2½ hours, 19 lb. of water was brought to the boil. "Is it possible", he asked, "that the very considerable quantity of heat produced in this experiment could have been furnished by so inconsiderable a quantity of metallic dust, and this merely in consequence of a change in its capacity for heat?"

His conclusion, therefore, was that the heat could not have been caused by the release of some fluid, but that it was *produced* by friction, and that it was equivalent to the work done in rotating the cylinder against the boring-tool which "excited and communicated molecular motion". Thus Rumford not only put an end to the 'caloric' theory, but proved and measured, for the first time, the convertibility and interchangeability of work and heat.

THE ROYAL INSTITUTION

Rumford's opponents in Munich, ignorant of the true stature of the genius in their midst, pressed the aged Elector again for his removal. Karl Theodor, seeking a way out of the dilemma, had the idea of appointing him his minister in London. Rumford accepted the appointment, only to learn on his arrival in England that the King thought it quite unacceptable for "a subject of the country to reside at the Court of his natural sovereign in the character of a minister from a foreign prince". Rumford was very disappointed, but decided to stay in London as a private person and to devote himself to scientific matters.

Meanwhile, the "secondary object" of the Society for Bettering the Condition of the Poor began to gain ground; so much, in fact, that Rumford and his friends decided to found a new independent organisation to carry it out. A new committee was formed, and its first meetings were held in the house of Sir Joseph Banks in Soho Square in 1799. Rumford framed the constitution and became Secretary (Sir Joseph was the Chairman) of what was to be called, after the granting of a royal charter in 1800, the "Royal Institution of Great Britain".

Rumford's prospectus to attract subscribers was a brilliant essay on the "slowness, indifference, and jealousy under which improvements make their way", and on the "influence of habit, ignorance, prejudice, suspicion, dislike of change, and the narrowing effect of the subdivision of work into many petty occupations . . . the scorn of improvement, the greed for wealth, the spirit of monopoly and of secret intrigues among manufactors". He then outlined the part to be played by the scientist in modern society. "Between workmen and merchants comes in a class of men who have a great and essential task to perform. These men are Philosophers, who have devoted themselves to the labour of observing, comparing, analysing, inventing. . . . Invention seems to be peculiarly the province of the man of Science; his ardour in the pursuit of truth is unremitted; discovery is his harvest; utility his reward." The prospectus attracted great public interest in the new Institution. A house was bought in Albemarle Street, and Rumford moved in to supervise the reconstruction work. He also engaged Dr. Thomas Garnett, of the Andersonian Institution at Glasgow*, as the first lecturer. The Royal Institution got off to a flying start: "It is not only the fashion, but the rage", Rumford wrote after the opening. It was the first research centre in the world linking scientists and manufacturers, but for the Londoners it was mainly their first chance to sniff the air of a new age of mechanical miracles. All classes flocked to the lecture hall, but it was precisely this success as a scientific "talking shop" which Rumford resented. He wanted the emphasis laid on workshops and schools for mechanics with a model exhibition of inventions, old and new. A serious rift developed between him and the other managers, with the exception of Sir Joseph, who was very much on his side. Rumford could not get on at all with Dr. Garnett, who soon left. However, if Rumford had done nothing for the Institution but choose a shabby young man from the West Country as assistant lecturer in chemistry, he would have deserved pride of place in its annals. For it was Rumford who discovered the mind of a genius in Humphry Davy.

The success as a lecturer of Garnett's successor, Dr. Thomas Young—who formulated the theory that light is a form of wave motion—only helped to increase Rumford's "morbid sensitiveness and irritability". In May 1802, he left the Royal Institution, the capital and England, never to return. It is a matter for conjecture whether his departure saved his creation from an early death, or whether it would have played a still greater part in Britain's scientific and industrial life had his plans been carried out.

Rumford spent the remaining twelve years of his life in Paris. He married the beautiful, witty, pleasure-loving widow of the great Lavoisier, but this turned out to be one of the most unsuccessful marriages on record. He continued his research work, but he seems to have been disliked by most French scientists. Some apparently hated him so much that they bribed his mechanics to reveal the secrets of the pieces of apparatus they made for him. His theory that heat is transmitted by rays met with their contempt and opposition. For the Parisians he was a ready object for ridicule, riding in a carriage with extra broad wheels, dressed completely in white, including hat, in winter (because it would keep off the "frigorific rays"). The disgruntled and lonely misanthrope lived with his daughter in a large house in Auteuil, and it was there that he died in August 1814, a few weeks after Napoleon's defeat. He is buried in the cemetery at Auteuil.

His last essay was an attempt to convert the English to the art of making and drinking good coffee—alas, as unsuccessful as his fight against the folly of the open fire.

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The Royal Institution, H. Bence Jones, London, 1871.

The Complete Works of Count Rumford, American Academy of Arts and Sciences, Boston, 1870.

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* As was recalled in last month's issue of DISCOVERY (p. 38), this Institution was the precursor of Glasgow's Royal Technical College.

TELEVISION OUTSIDE THE ENTERTAINMENT FIELD

GEOFFREY PARR
M.I.E.E.

Whatever the criticism of television as an entertainment, it is proving a valuable aid to industry and research and new applications are being found as time goes on. The television camera is the answer to the often-expressed desire to have "an eye on a stalk", and as it is comparatively easily replaced it can take the place of a human observer who might be exposed to undue hazards or might wish to be in two places at once. When used in conjunction with a large screen receiver it gives a presentation that cannot be achieved by any other means.

Admittedly, it is always possible to make a record of an experiment and view it by means of a cine projector and screen, but the time delay in processing may be the vital factor which prevents full advantage being taken of the observations. With the television camera it is possible to see how an emergency or change in conditions may be dealt with on the spot, and the sense of immediacy is an added advantage both to operator and onlooker.

As the first example we may take the use of television in medicine and surgery (although this can hardly be classed as an industry). The television camera installed above the operating table enables the surgeon to demonstrate his technique to a much wider audience than could be accommodated in the theatre itself. As Mr. H. J. B. Atkins, a practising surgeon, said at the recent Television Convention:

> Whereas a good surgical teacher may have five or six students at his back in any ordinary operating session, the state of the theatre during a Congress is quite unmanageable, and the opportunities for a vast audience to derive any substantial benefit from the experience is slight.
>
> With television the scene is transformed. The operation is conducted in the untrammelled atmosphere which is proper for the consummation of good surgery, and the visitors are able to follow every detail of the procedure in comfort.

It is gratifying to note that one of the first permanent television installations for surgical teaching was installed in the theatre of Guy's Hospital. The added advantages of large screen projection make the demonstration of small surgical operations available to a wider audience than could have ever been accommodated in the ordinary theatre. Examples of this are shown in Figs. 1 and 2. Fig. 1 shows the operation for a cleft palate being performed under the camera and thus being visible to a large audience in a remote theatre, and Fig. 2 shows in a striking way the ease with which a lecturer can demonstrate on the living body.

REMOTE CONTROL

From remote viewing it is only a step to remote control. The television camera can be used to convey the image of a remote happening, experiment or meter reading to an operator, who can make adjustments at a safe distance and observe the effects. An example of intricate remote manipulation is shown in Figs. 3 and 4. This apparatus, developed by the Du Mont Laboratories and the Argonne National Laboratory, U.S.A. is used to handle radioactive material which would be dangerous to an unprotected operator. The television camera is fitted with stereoscopic lenses and a double picture of the apparatus is shown on the receiver screen. The operator wears Polaroid glasses to resolve the stereoscopic picture; and by means of the hand manipulators is able to pour liquids from one flask to another under completely safe conditions.

On a larger scale, the camera can be used to control heavy loads, and at a recent Mechanical Handling Exhibition a crane was demonstrated under the control of an operator who did not have a direct view of the work he was handling. (Fig. 5.)

More recently, television equipment of a similar type has been used in the dismantling of the heavy water pile of the Canadian atomic energy project at Chalk River.

UNDER-WATER TELEVISION

One of the more spectacular achievements of television was the location of the sunken submarine *Affray* in 1951. The camera used for this is shown in Fig. 6, surrounded by a ring of floodlights for illuminating the sea depths. Apart from being able to operate at depths that would be dangerous for divers, the camera is easily manœuvrable, and if accompanied by remotely controlled 'hands', it can take the place of men whose lives are too valuable to risk at great depths.

Apart from its obvious uses in locating sunken objects, the camera opens up a wide field of exploration of the sea bed and marine life in general. The Scottish Marine Biological Association has already proved the value of underwater television equipment for the examination of plant and animal life at considerable depths, and those who have seen the quality of picture already obtained by Dr. Harold Barnes of the Millport research station are considerably impressed with the possibilities of this technique for marine biological research.

INDUSTRIAL EQUIPMENT

The use of television in industry generally involves the transmission of an image over short distances, and if the radio frequency link is omitted the equipment can be correspondingly simplified. A modern lightweight camera measures only 12 by 6½ by 4½ in. and with its tripod and spare tube can be packed in a case weighing only 13 lb. All the controls can be operated from the receiver unit which can be situated at any distance up to 300 yds., and this provides the scanning and synchronising signals for the camera. The whole equipment can thus be transported to any convenient site and left without attention for as long as desired.

In the absence of the radio broadcast requirements it is

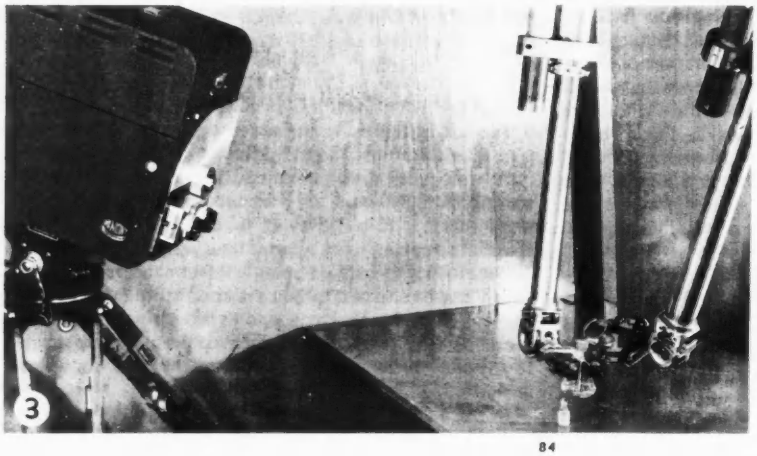

FIG. 1. The International Dental Conference held in London in 1952, saw an operation televised and projected on to a large screen. A television camera was mounted above the hospital operating table and larger-than-life close-ups of a cleft palate operation were seen by the delegates in the viewing theatre five floors below.

FIG. 2. Image of the human eye scanned by a television camera and projected on to a large screen for demonstration.

FIG. 3. Stereoscopic television camera focused on a mechanical manipulator for radioactive materials.

FIG. 4. The chemist views the stereoscopic picture on the receiver screen through Polaroid glasses and works the mechanical manipulator at a safe distance.

FIG. 5. During the 1952 Mechanical Handling Exhibition at Olympia a radio-controlled crane was operated by an engineer using television, out of sight of the crane.

The picture shows the radio-controlled crane grab and the Marconi television camera in the background.

FIG. 6. Marconi underwater television camera in its special pressure case, and adjustable lighting gantry. The camera is remotely controlled and the port—through which the camera 'shoots'—is seen in this front view. For downward vertical 'shots' the gantry and camera case can be swung through 90° on the trunnion.

These photographs are reproduced by courtesy of the following organisations: Figs. 1 and 6, Marconi's Wireless Telegraph Co. Ltd.; Fig. 2, Cinema Television Ltd.; Figs. 3 and 4, Du Mont Laboratories and Argonne National Laboratory; Fig. 5, Fox Photos Ltd.

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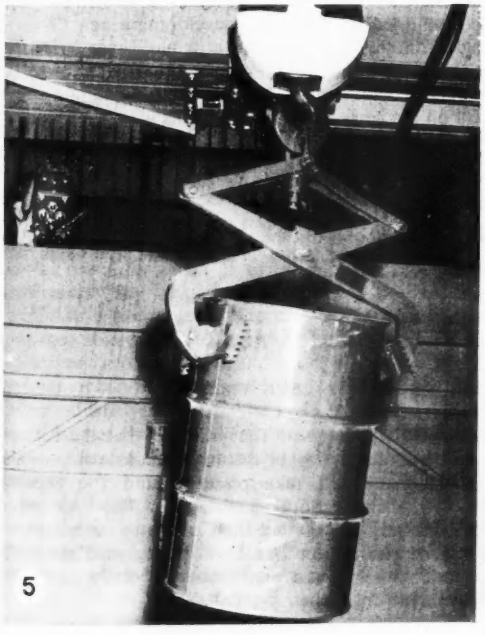

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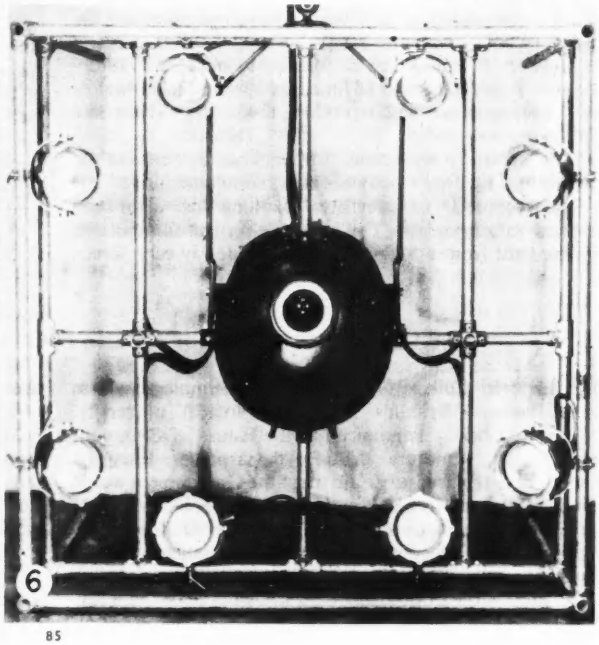

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possible to modify the scanning system, especially where fineness of detail can be sacrificed. This leads to a reduction in the frequency band-width employed and simplification of the circuits—a useful feature when it is desired to transmit over existing communication channels.

TELEVISION IN ASTRONOMY

It has already been shown that the latest form of camera tube is more sensitive than the fastest photographic plate for the same exposure time. A more important feature of the modern camera is that the photo-electric emission from the sensitive 'mosaic' is proportional to the amount of incident light received, even at very low intensities. The camera, therefore, is more accurate than the photographic plate for recording very faint images in astronomical photography. The photo-electric mosaic also possesses a 'memory', in that the charges stored on its surface remain long enough to be built up by successive exposures, and there is thus a close similarity between the television camera and the photographic camera with the advantage of increased sensitivity. It is probable, therefore, that the photo-electric camera will be used for reproducing faint star images on a recording screen for subsequent photography. By the choice of photo-electric material the camera can be made sensitive to a particular range of wavelengths, such as the infra-red and ultra-violet.

OTHER POSSIBILITIES

The applications of television technique already mentioned are fairly obvious examples of the "eye on a stalk", but there are many other possibilities which are only now being realised. The uses of high-speed photography in analysing rapid movement are well known, but this entails elaborate equipment and an inevitable delay before the results can be shown on the screen. A television camera can also take an instantaneous picture, and its 'memory' will enable the image to be reproduced a second or so later. It would thus be possible to observe a rapidly moving object by a series of timed glimpses on the principle of the stroboscope and reproduce them at a slower rate on the receiver screen.

This has the merit that adjustments can be made to the mechanism and the results observed simultaneously.

The technique of television scanning has also been applied to microscopy, the object being transilluminated by the light from a high-intensity cathode-ray tube screen and the resulting image being amplified by a photo-multiplier and shown on a receiving screen. It is claimed that the reproduced picture is superior to that from an ordinary projection system in brightness, contrast and resolution.

The scanning technique also enables particles in the field to be automatically counted and sized.*

It is obvious that this new method of microscopic investigation will prove of value to research workers who cannot invest in an expensive electron microscope, and the scanning microscope may prove superior to the electron microscope in quantitative measurements.

So far the question of colour has not been considered. In radio transmission the colour television system involves circuits of much greater complexity than in monochrome transmission, and the frequency band-width required for correct rendering of detail is much wider. Industrial equipment operating with a cable connexion between the camera and the receiver gives a better opportunity for use of colour without adding too much to the cost of the system. In certain applications, coloured reproduction will be essential if full advantage is taken of the television picture for educational purposes. A surgical operation, for instance, will only be fully instructive if the details of the tissues are shown in their natural colour, and many chemical changes require close observation of colour by the remote operator.

In the final development of the television aid to research we may expect to use a transportable colour camera and projection type reproducer with an accompanying collapsible screen similar to that of the miniature cinema. The operator will be able to select one of a number of lenses to give a close-up of part of the scene, and, of course, no additional lighting will be necessary.

The television camera offers a new and unique medium for educational demonstrations, but its properties can only be exploited to the full by developing a new demonstrating technique to suit. Thus a demand may arise for specialist lecturers who will combine a thorough knowledge of the subject with ability to make a good running commentary on the work being shown. This would infuse new life into otherwise dull scientific subjects, and it is to be hoped that some lectures in future will prove as attractive as other television displays that are officially classed as entertainment.

* "The Flying-spot Microscope", F. Roberts & J. Z. Young. *Proceedings of the Institution of Electrical Engineers*. Pt. IIIA. **99**. 20, 747.

BRITAIN'S FIRST 'TECHNOLOGICAL UNIVERSITY'

The Imperial College of Science and Technology will in effect become Britain's first 'technological university' when plans briefly announced in the House of Commons on January 29 mature. Mr. Boyd Carpenter, Financial Secretary to the Treasury, said that "the Government would put further resources at the disposal of the University of London for the purpose of major expansion of the Imperial College". His precise wording seems to indicate that its status as a constituent college of the university may not alter.

At present the College has 1650 students, all of them full-time, and the aim is to raise this number to 3000 by the end of 1962.

Mr. Boyd Carpenter said that in order that the current work of the College may be disturbed as little as possible the expansion should take place around the existing site of the College in South Kensington. The Chancellor of the Exchequer has invited the College to submit plans based on the assumption that it will be regarded as having first claim on other parts of that area as it becomes possible to release them from their present uses.

THE SCIENCE OF ORCHESTRAL INSTRUMENTS: SOME RECENT WORK

E. G. RICHARDSON
B.A., Ph.D., B.Sc.

It is unnecessary perhaps at the outset to dwell on the nature of tone quality or timbre. Most musicians nowadays are aware that what the scientist calls the 'note' of a musical instrument can be split up into a number of simple 'tones' and that it is the relative number and magnitude of these components that determine timbre. This tells us, for example, why a violin and a clarinet or even two violins do not sound the same when producing a note at a given fundamental pitch. In many cases these component tones are members of the harmonic series, i.e. their frequencies bear simple ratios to the fundamental or component of lowest pitch, but again often other tones—not harmonics—intrude, whose origin is to be traced to the vibrations of the unchanging parts of the instrument, such as the belly of the violin or the metal tube of the trumpet, and which do not alter much when the player passes from one note to another.

The past twenty years have seen the development of the electrophonic organ, in which oscillations of electrical origin are transformed into audible sounds that imitate the timbre of the pipe-organ. We now wait upon improvements in loudspeakers, especially those which will handle larger power without distortion, before the electrophonic organ can replace the best sort of pipe-organ or the orchestra.

The apparatus which had to be constructed to synthesise tone electronically for these new musical instruments served equally well for the analysis of tone in the old. The development of electronic analysis in turn directed attention to defects in the conventional instruments and suggested the means of their improvement.

The basis of such analysis is that a record of the steady wave-form of the sounds produced on the musical instrument note by note is made on a disc, magnetic tape or talkie film, and this record is then played back to a set of electric filters which respond, each to its own proper frequency, when this particular frequency is present in the note to be analysed. The response of each filter may also be made proportional to the loudness of the component in the note to which it responds. In some cases the instrument may be played directly to a microphone connected to a 'sound-level recorder', with the aid of which one may sweep through the whole gamut of frequencies to obtain an 'acoustic spectrum' (see Fig. 3).

In our laboratory at Newcastle we use several methods of sound analysis, but in the main we prefer one of two according as the sound is to be analysed while it is being produced or whether a record is to be made for subsequent analysis.

In the latter case we record on film, using a ribbon microphone, amplifier and cathode-ray oscillograph so that the record is obtained as the trace of a single black line on a white background (or vice versa) corresponding to those of Figs. 5–7. In the oscillograph a beam of electrons is normally shot on to a luminescent screen, but is made to move up and down in step with the sound waves picked up by the microphone after the sound has been converted into electrical waves and amplified. In the camera which photographs the movement of the spot formed where the electrons hit the screen, there is a sensitive film moving horizontally at constant speed. The resultant wave-form development on the screen is a combination of the vertical movement of the spot and the horizontal motion of the film. Before the film can be analysed it must be converted into a record of the 'hill and dale' type by blackening the whole of the film which lies to one side of the wavy line, leaving the other side transparent. This is done on the positive from the negative obtained in the camera. It may be noted, by the way, that we could get a record of the 'hill and dale' type directly by using an equipment of the 'talking film' type, but we prefer the oscillograph for its more faithful reproduction, in spite of the labour involved in blackening a short length of film.

A short length of the film comprising three or four complete wave-lengths is wrapped round a glass cylinder (*C*, Fig. 1), at the centre of which is the filament of the special lamp *L*. By means of the constant-speed motor *E*, the glass cylinder is rotated, and as this happens the lamp shining past the film and the slit *D* casts an image of a narrow section of the film on the photo-electric cell *P*. The wave-form on the film is thus converted back into synchronous electric waves in the circuit containing the photo-electric cell and the analyser *A*. This electric-wave analyser is like a wireless receiving set in principle, but it covers the gamut of audible sonic waves instead of the ultrasonic waves which are used to 'carry' broadcast music. One proceeds to tune the analyser through its range of frequency from 20 to 20,000 vibrations per second, picking up the various harmonics of the wave-form and noting the readings of the voltmeter which records the intensity of each constituent signal. (This instrument gives, in fact, an indication like that often given on a wireless

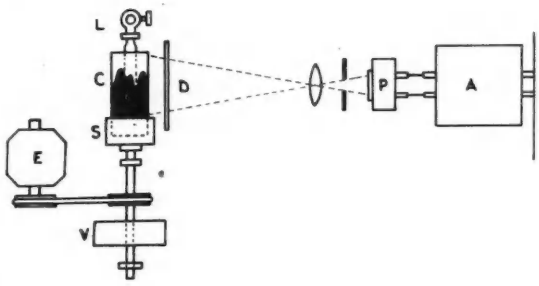


FIG. 1. Photo-electric apparatus for analysis of transient sounds.

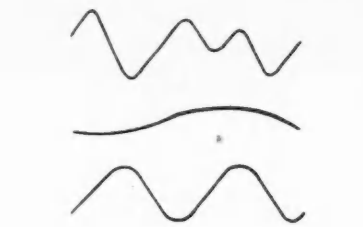


FIG. 2. A complex note analysed into its components. The wave-form of the complex note is seen at the top: the wave-forms of the three harmonics comprising it are shown underneath. The heights of the columns indicate the relative intensities of the harmonics.

set to indicate when the maximum of tuning-in to a station is reached.)

Fig. 2 shows an example of this analysis for a comparatively simple sound. The upper curve shows one complete period of the wave-form as recorded by the oscillograph. Underneath are three simple tones into which it was analysed by the machine. These are also shown in relative magnitude by the height of the black rectangles on the 'acoustic spectrogram' at the bottom. In this simple case the components were true harmonics and comparatively low in the series. When the intensity of a musical instrument is raised, or when we are dealing with complex systems like a bell or the human voice, the components are no longer all harmonic to the fundamental and, moreover, they cover a greater portion of the musical scale so that our analysis may extend to the detection of a score or more of partial tones within the frequency range of the apparatus.

Now let us turn to results obtained by this kind of analysis. First of all, let us consider what has come to light about the acoustics of the orchestra in a general way, and then pass in rapid survey over information peculiar to the chief types of instruments.

THE ORCHESTRA AS A WHOLE

The complex subjective process which we call listening to music involves the three P's of science: Physics, Physiology and Psychology. The aspects of musical acoustics with which we are concerned in the laboratory or instrument factory are mainly the physical.

One question may properly be answered in physical terms merely; that is, how the sounds of one instrument, played solo, may be distinguished from each other. Every musician knows that this is mainly a question of timbre, which means the number and magnitude of the overtones (harmonic or inharmonic) which accompany the fundamental or nominal note which the player intends to produce. The oboe and the clarinet each sounding A have then different spectra and wave-forms (Fig. 3) and so can be distinguished. But this distinction is often uncertain between two instruments at certain parts of the scale; thus, for example, the violin's steady tone is very like that of the oboe. Yet many people can distinguish a violin solo from an oboe solo.

How then does this happen? One factor is that the timbre of an instrument is not constant over the whole of its range, so that the quality just cited is unlikely to persist when the soloist passes from a note of medium pitch to one that is higher or lower. Certain fixed frequencies in the build of the instrument like those of the belly of the violin, may intrude in the notes of variable pitch which the player wants to produce. Another factor is the difference as between different instruments in the starting and build-up of steady notes, the scrape of the bow, the tonguing of the reed, etc. The first of these characteristics is called *formant*, the second *transient*, though sometimes the first word is used to cover both. The removal of the transients can make a great difference to the ease of distinguishing between different instruments of different or even of the same types.

The formant, in the narrower sense of the word which I prefer, is that feature in the sound of an instrument which distinguishes it from another of the same breed and is largely a question of the existence of resonances which may be excited in the soundboard or box to which the primary tone-producer, vibrating string, reed, etc., is coupled. (In speaking of 'soundboard' one must use the word in the general sense to include all neighbouring bodies which can be set in forced vibration. For instance, it ought to include the cavity resonator formed by the player's lungs, whether he is playing oboe or violin!)

Another factor which must be considered is the directional characteristic. An instrument with a definite soundboard like the violin probably radiates best in the direction perpendicular to the board, a wind instrument in the direction of the bell, though this direction may be changed by local reflecting surfaces.

The soundboard should vibrate as a whole up to as high a pitch as possible. If it tends to subdivide into segments—some moving out while others move in—their mutual

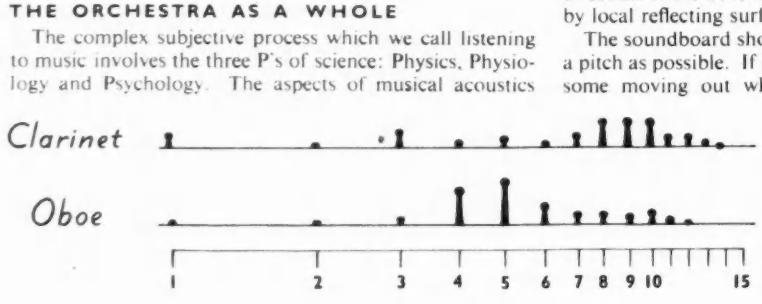


FIG. 3. Acoustic spectra of clarinet and oboe. References to the scale at bottom indicate the harmonics present in the mixed note of each instrument: 2 stands for second harmonic, 3 for third harmonic, etc. The heights of the dolls indicate the quantity of each harmonic present.

effects at a distance will cancel each other and the sound will not radiate well.

This directivity is only, however, valid for high pitch. At low frequencies it fails and the sound spreads equally in front of the player. (Physically this is the same factor that intervenes when sound passes through a doorway: high-pitched sounds pass mainly straight ahead in a beam, but low-pitched sounds spread round a corner.) This is a matter of some importance when one wishes to localise the sound from a particular instrument in the orchestra; for instance, a good violin, in the sense of one which if used for the solo part in a concerto will stand out from the mass of other strings. It is believed that low-frequency transients help also in this respect.

A factor of similar origin which will make localisation of the music of the wind more certain than that of the strings in an orchestra, is that the former are mostly playing parts which are not doubled, whereas the latter show a 'chorus effect'. The fact that two or more strings playing the same part can never exactly reproduce each other's effect as to loudness, pitch and timbre and time of initiation and duration of transients (even if they were played by a machine) masks any directivity, introduces slight but rapid vibrato and smudges individual characteristics. The same is true of an organ solo stop played over chorus foundation stops on another manual.

Since one usually listens to music—whether directly or over the radio—under circumstances in which some reverberation is superimposed on the original sounds, it is proper to consider the modifications introduced by the acoustics of the buildings in which the music is produced or reproduced. The general effect of excessive reverberation is a smudged rendering. The desirable amount of reverberation depends on the individual's taste and experience. Some reverberation is desirable if only for the sake of the players who would find a chamber from which echoes had been entirely eliminated very unsympathetic to their efforts. What one is willing to tolerate in this respect is largely a matter of what one is accustomed to. Since we most often hear a large organ under a high vault and a piano in our own drawing-room, we incline to favour long and short reverberation times respectively for these two instruments.

Another concomitant of reverberation is loss of directivity. In a hall with hard wall surfaces sounds will bombard the listener's ears from several directions at once, so masking the direct sound by which he estimates the true direction of the source. Furthermore, there will be marked foci and deaf spots at certain frequencies in such a chamber, a condition which is not only unfair to the audience but makes it impossible for the radio engineers to locate their microphones to give faithful reproduction.

From the point of view of the latter persons indeed, the ideal would be to diffuse the sound equally in all parts of the auditorium, a condition secured in broadcasting studios by lining the walls with half-cylinders or other protuberances of varying size. This would, however, further spoil the directivity by which, as I have already pointed out, the audience is able to judge which instruments are playing at a given instant and to pick out the soloist in a concerto.

Fortunately, a way out of this dilemma is suggested by a recent discovery in the use of the 'public address system'. The disadvantage of the common use of loudspeakers to amplify sound, e.g. of the voice of the preacher in a large church, is that the output of the nearest loudspeaker to an auditor, since it seems usually louder than and slightly in advance of phase over the human speaker, gives the impression that it—the mechanical source—is the true source. But if the reproduction over the amplifying system is delayed so that it arrives some millionths of a second *later* than the direct sound—which can easily be done by making a record of the sermon on magnetic tape and picking it up to feed the amplifiers at a point a little farther along the tape, so as to produce the required delay—the sound is estimated to come from the *original* source and yet is amplified. Londoners may hear such a device in action in St. Paul's Cathedral, and although, to my knowledge, it has not been applied to music, it seems to have possibilities in instances such as those I have cited where loss of directivity would be a disadvantage.

FIG. 4. Violin, indicating the positions of bass-bar (BB) and sound post (S) within the belly.

INDIVIDUAL INSTRUMENTS

Strings

The problem that will most interest string players is: what, scientifically speaking, differentiates a good violin from a bad one? Put so baldly, the problem seems puerile, but it is, in fact, far from easy to tell a *good* modern violin from a classical one by means of scientific apparatus. Prof. Saunders at the University of Harvard has spent about twenty years trying to discover what he calls "the secret of Stradivarius", and although some facts have emerged, a good deal on the psychological side remains to be explained.

In a set of experiments in which J. Heifetz took part, three violins, A, B, C—one a good old and two modern types—were played behind a screen, while a critical audience was asked to 'find the Strad'. This they were unable to do—that is to say, one-third named A, one-third B and the remainder C as the veritable old master. Heifetz himself, however, claimed that he could tell a difference in ease of tone production or 'singability' while playing them. Perhaps the older violin, from constantly being played on, had acquired with age greater 'efficiency' as a music-maker.

Not much can be learnt by comparing acoustic outputs of violins over their range except that the really bad ones will have in their formants a few pronounced and strongly separated resonances in each of which a 'wolf' lurks; whereas these resonances ought to be reasonably and closely distributed over a range of four octaves. Much can, of course, be done to improve a poor violin; altering the coupling between the strings and resonators by shifting bridge, bass-bar and sound post, whose positions are indicated in Fig. 4.

Prof. Skudrzyk of Vienna emphasises the importance of

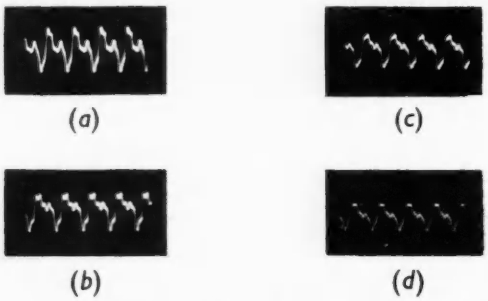


FIG. 5. Wave-forms of four flue organ pipes identical in form and of pitch C,522 vibrations per sec. but made of different materials: (*a*) 60% lead, 40% tin; (*b*) 15% tin; (*c*) 50% tin; (*d*) all tin.

the radiation by a good violin of transients and of low frequencies in order to make them stand out in solo work. From this point of view tests behind a screen are inadequate to represent the effects of playing the instrument on the concert platform, particularly in concerti.

He and other physicists have tried to pin-point the effects of material and varnish. The general conclusions are what one would expect; the wood should possess good elasticity and small internal friction. The purpose of the varnish is to reduce the latter, but since a varnish suffers a chemical change with age we cannot be sure that the old violins are, in respect of internal friction, in the same condition as when contemporary players used them. In any case, varnishes have been so much developed by the chemists in recent years that the modern violin-maker ought to be able to do better than the old masters in this respect.

Wind

Whether the wind instrument is one of a distinct class, like the orchestral wind, or occurs in stops all of the same pattern as on the organ, basically its sound is that of a column of air set in vibration by an edge-tone (whistle type) or reed. In the former a jet of air debouching through a slit from a wind-chest or from the human lung strikes a sharp edge and is set in oscillation at a frequency eventually governed by the column of air acting as resonator. In the brass we have virtually both types of excitation, for the lips of the player act like a double reed while an edge is furnished by the more or less sharp constriction where the cup mouthpiece adjoins the tube itself.

The column has either a fixed length so that its possible notes are limited to the fundamental—in theory, though it is often unattainable—and its harmonics, or it is variable by the use of side-holes. It is now possible to calculate the pitch of such a system if one knows the position and acoustic 'resistance'—to borrow a term from the electrician—of the side-holes and of the termination or bell-mouth. The principal drawback to the practical use of such theoretical predictions of the hole-size and position on the wood-wind in place of the old hit-and-miss method is our uncertainty in ascribing precise values to these resistances. Work is, however, proceeding on this problem.

The material of the tube seems not to have such a marked effect on the output as some organ-builders suppose. Provided the tube is not made of very lissom material, it will sound—even shellacked paper will serve—though there may be differences in harmonic development. In Fig. 5 are shown tracings of the wave-form of four metal diapasons (C,522) of different material but identical shape, and it will be noticed that there is some change in the strength of the second and third harmonics.

The nature of the coupling between exciter and resonator is a matter that has interested workers in musical acoustics of late. In a flue-pipe the edge-tone—which, unmodulated, would normally have a pitch proportional to the wind velocity—is brought into consonance with one of the natural modes of vibration of the column—the fundamental at moderate pressure, the overtones at higher ('overblown') pressures. Exceptionally, if the pipe is 'underblown', a reshuffling of the pendulations in the jet takes place whereby either the fundamental or its octave again appear. Although these underblown tones are undesirable they often appear transiently as the blowing starts. Thus, in the oscillograph record of the commencement of sounding of the diapason pipe which I reproduce (Fig. 7*a*), the octave is apparent in the transient for about one-tenth of a second though not in the final wave-form.

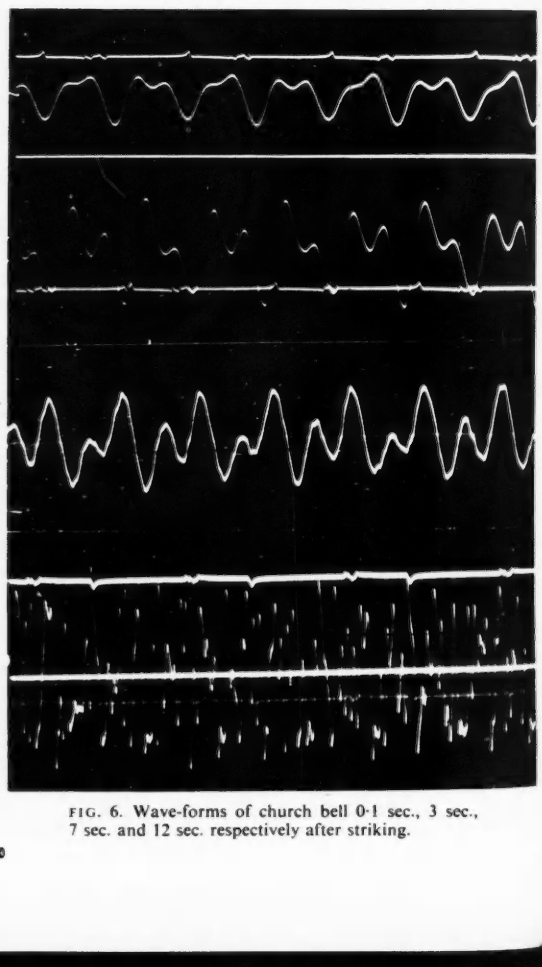
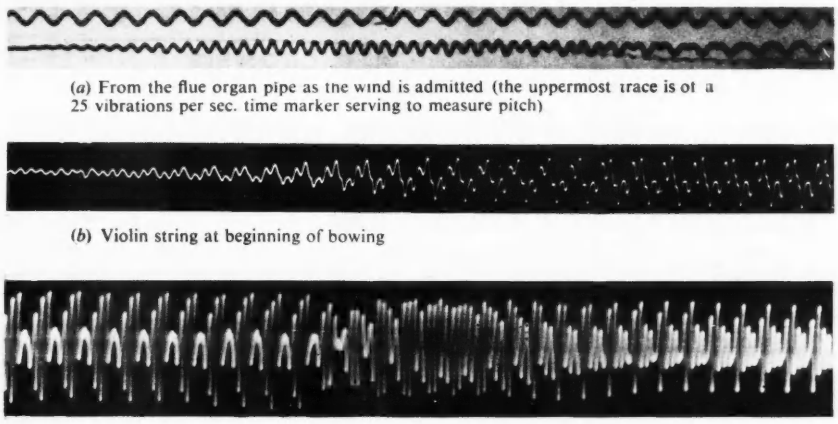


FIG. 6. Wave-forms of church bell 0·1 sec., 3 sec., 7 sec. and 12 sec. respectively after striking.



(*a*) From the flue organ pipe as the wind is admitted (the uppermost trace is of a 25 vibrations per sec. time marker serving to measure pitch)

(*b*) Violin string at beginning of bowing

(*c*) Bagpipe, as the player passes suddenly from B,513 to C,570 vibrations per sec.

FIG. 7

WAVE-FORMS OF SOUNDS

The build-up of pressure in this pipe lasted about a fifth of a second. Transients also occur on orchestral wind instruments when the player passes 'portamento' from one note to another (Fig. 7*c*). The process of 'voicing' by which an organ-builder gets the pipe to speak as he wants it, cutting the mouth and making notches in the lower lip, is a mysterious art which I hope will be clarified in a scientific study of the process being made by Mr. Mercer at the University of Southampton.

In a reed-pipe the coupling between reed and column may be either tight or loose. If the reed is slim and rather inelastic because of its moist condition—like many orchestral reeds, including the brass-player's lips—it accommodates itself to whatever note the player and/or the wind pressure impose on the column. In the organ reed-pipe, however, the reed is strong and elastic, and if reed and column are tightly coupled the two can only sound sympathetically when the length of the pipe is adjusted to synchronism with the reed, otherwise the system remains silent.

The transient sounds of a reed-pipe are—like those of the violin (Fig. 7*b*)—usually smaller copies of the final steady state and do not comprise extraneous noises.

Bells

The scientific interest in the sound of bells is centred on the remarkable fact that while from theoretical considerations it ought to be one of the most complex of musical instruments, yet through the ages the craft of the bell-founder has made the sound of the church bell pleasantly simple in the sense that most of the overtones produced by striking it at the right place are harmonic or quasi-harmonic. This he does mainly by varying the thickness and moving the sound-bow—the place at which the surface changes from convex to concave.

The first six partial tones of bells in a carillon are usually adjusted to lie as follows:

(1) 'hum-note'—the lowest;
(2) 'fundamental'—one octave above hum-note;
(3) 'minor third' above fundamental;
(4) 'fifth' above fundamental;
(5) 'nominal'—one octave above fundamental;
(6) 'harmonic decime'—a major third above nominal.

(It will be noted that this use of the term 'fundamental' is unorthodox.) Roughly speaking, the pitch of the hum-note is inversely proportional to the circumference at the sound-bow.

A peculiar feature of bell-timbre is the 'strike note', the tone most prominent to the ear and the one which is intended when the pitch of the bell is named. It seems that this is a beat-note formed between two of the higher partials, falling about one octave below the fifth partial or, as some maintain, the fifth partial itself wrongly judged by the ear to be an octave lower than it really is.

Whereas the nominal is most apparent immediately after striking, it disappears quickly, leaving components (1) and (3) as the strongest. After some ten seconds only the hum-note remains. I have a record, too long to reproduce in full, given to me by the late Prof. Taber Jones, of the sound of a church bell. Snippets from this are given in Fig. 6 to show the change of timbre as the sound decays.

This survey by no means exhausts all recent work on musical instruments, but there is a limit to what can be covered in a single article. The instruments and topics to which I have referred do in fact comprise those which physicists working in musical acoustics—all too few, unfortunately—have been interested in during the past decade.

ACKNOWLEDGMENT

The author wishes to thank a number of friends for loan of records, viz. Dr. E. O. Cook, Prof. F. A. Saunders, Dr. J. M. A. Lenihan and the late Prof. A. Taber Jones.

THE IDEA OF ORGANIC EVOLUTION*

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Evolutionary explanations, in the general sense of accounts showing how a given state of affairs can be derived from an earlier, simpler state, are among the oldest known to science. The earliest Greek explanations of the origins of things were of this kind. The novelty of the modern theory of organic evolution, first effectively put forward in the eighteenth century, was that it applied the methods of seventeenth-century physics to the problems of the origin of organic forms.

The modern theory of organic evolution contained two new and fundamental elements. First, on the basis of a systematic survey of evidence (principally derived from comparative anatomy, palaeontology and the study of heredity), it asserted that as a matter of historical fact all plants and animals have descended, with modification, from common ancestors. Secondly, it attempted to explain this historical process by the classical method of deducing it from a theory of causes. These two elements are quite different in character. Since the eighteenth century, evidence for the historical assertion has accumulated steadily, whereas one causal theory has succeeded another, each with its special advantages and difficulties.

THE FIXED SCALE OF NATURE

The basic evidence from comparative anatomy that was ultimately to be explained by the theory of evolution was first collected by biologists who gave it an altogether different explanation. From the pioneer investigations of Aristotle and Theophrastus in Greek times, down to the extensive researches of a whole series of botanists, zoologists and anatomists in the sixteenth, seventeenth and eighteenth centuries, biologists built up an ordered picture of the kinds of plants and animals that existed and of the relationships between them.

They discovered the essential similarity of structure in all members of groups of plants such as the grass family, the daisy family, the pea family and the rose family. Similarly, when they investigated the anatomy of fish, birds and mammals, they found structural similarities (as well as differences) between the three great groups of back-boned animals; they recognised that the three groups showed three different kinds of variation on a basic vertebrate plan (see Fig. 1). The study of comparative anatomy and the development of schemes of classification reacted upon each other.

The early work of classification culminated in Linnaeus's great *Systema Naturae*, in which, in a series of editions from 1735, he attempted to name every known kind of organism (establishing the modern binomial method whereby each organism is given a generic and a specific name, e.g. *Bellis perennis* for the common daisy), and to place each species, genus, order and class in a logical relationship with all the others.

Linnaeus's immediate object in *Systema Naturae* was to produce a convenient system, by which any organism could be run down by means of a key, named and classified. This was an artificial system in that its primary purpose was to effect a method of identifying and cataloguing particular specimens; but, in common with the majority of seventeenth- and eighteenth-century biologists, Linnaeus held that the artificial systems which man could devise should aim at ultimately expressing the *true* relationships between organisms: they should in fact approximate to the 'natural' system expressing what he called "the sovereign order of Nature". It is important to understand the principles underlying this seventeenth- and eighteenth-century conception of the 'sovereign order of Nature', because they both prepared for, and were re-interpreted by, the evolutionary explanation of the organic world.

First, it was an essentially unchanging order in which not only the fixed and unchanging biological species, but also all the other objects and substances in the universe, from the stars and planets to the chemical elements, had each its appointed place and role. Although the traditional picture of the universe deriving from Aristotle had been radically altered by seventeenth-century mechanics and astronomy, the basic conception of a fixed universal order was retained.

What is most important, within the context of this article, is that Aristotle's conception of fixed species continued to be used in biology. Linnaeus conceived a biological species as something created by God with a given nature, or essence; it had been the same since the day of creation, and it would not change in the future. In reproduction, this specific nature was passed on, from one generation of individuals possessing it, to the next generation. So followed two important consequences: first, varieties within a species could be ignored as unimportant; and second, any differences observed between individual parents and offspring must be accidental to the essential nature of the species and certainly could not be used as evidence that a species could change. This conception of the essential fixity of biological species was supported by the work of Harvey, Redi, Swammerdam and others showing that 'spontaneous generation' (whereby living organisms were supposed to be produced from non-living matter) did not occur, and that a particular kind of living organism arose only from the egg produced by another organism of the same kind.

The second principle underlying the 'sovereign order of Nature' was that it was held that the 'natural' system expressing the true relationships between fixed organic species would show them to be arranged in what was called the 'scale of nature'—a ladder, so to speak, of which the bottom rungs

* This article concludes the series of four contributions by Dr. A. C. Crombie on the historical development of scientific method. The titles of the previous articles are as follows: The Invention of Scientific Explanation (Nov. 1952 issue); The Invention of the Experimental Method (Dec. 1952); The 17th-Century Revolution in Mathematical Physics (Jan. 1953).

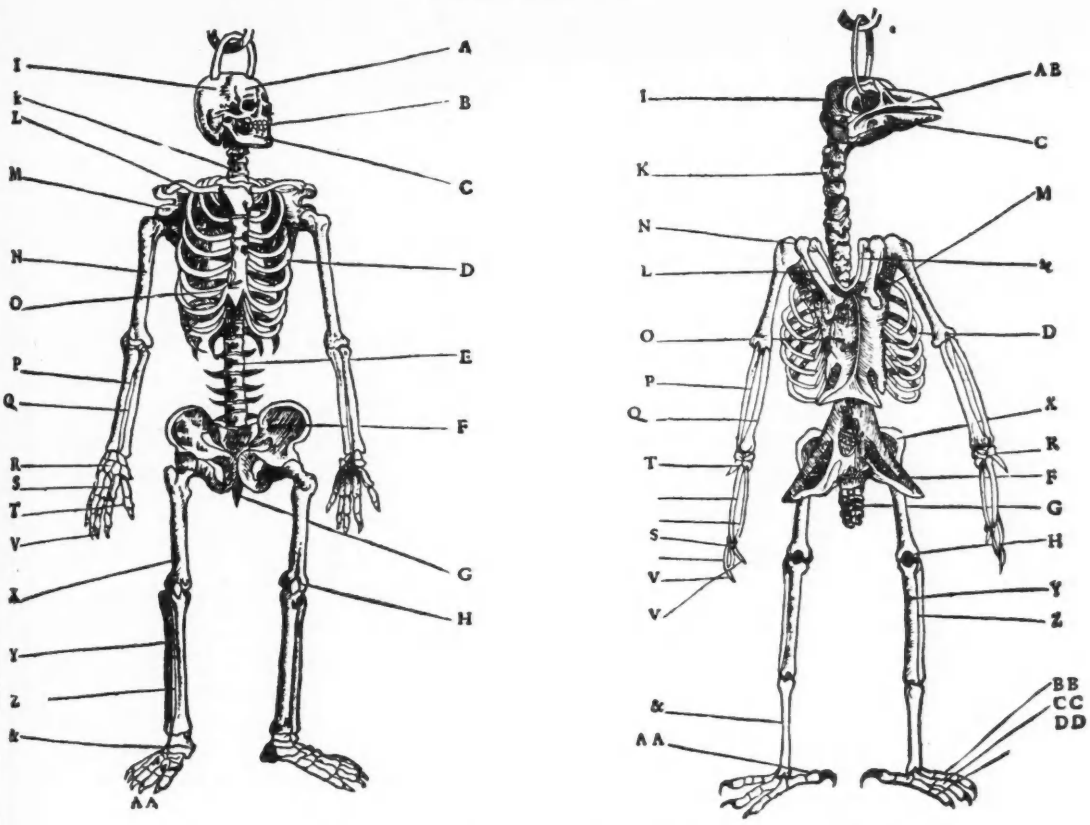

FIG. 1. The elucidation of the natural relationships between animals has owed much to comparative anatomists concerned with the differences and similarities in basic structure shown by the myriad members of the animal kingdom. The idea that the vertebrates, for instance, are all built to a common structural plan is very ancient, as is shown by these two drawings—comparing the skeletons of Man and of a bird—from Belon's *Histoire de la Nature des Oyseaux*, Paris, 1555.

corresponded to the most primitive living organisms, in their lack of structure scarcely distinguishable from non-living matter: ascending the ladder one next came upon the plants, then 'zoophytes' (sponges, etc.) and the animals; the final rung represented Man's position in the scale.

The first outline of this scale of nature had been made by Aristotle. In the early eighteenth century it was conceived as a single linear series of species ascending without gaps in continuity from bottom to top. Later eighteenth-century work in biology broke up the single linear scale into different branches, recognising the divergence, first of plants and animals, and then of subordinate groups, to give an arrangement suggestive of the branching of a tree, except that it showed gaps in continuity. Though giving rise to much extravagant speculation, the idea of arranging organisms in a scale played an essential part in preparing the way for the theory of evolution. Especially important was the notion of 'gradation' used in the seventeenth and eighteenth centuries, for example by the English anatomist Edward Tyson, who, in his study of the chimpanzee in 1699, said that by making

> "a comparative survey of this animal with a monkey, an ape and a man . . . we may the better observe nature's gradation in the formation of animal bodies, and the transitions made from one to another".

Thirdly, all the different parts of the universe were held to be so related as to make a harmonious whole, exhibiting what John Ray, in the title of his famous book which was published in 1691, described as "The Wisdom of God, manifested in the Works of the Creation". The parts of each organism were perfectly adapted to the functions they fulfilled in the organism, the organism as a whole was perfectly adapted to its physical environment, and the relationships between organisms were such that they preserved a harmonious balance, increase in numbers of one being checked by others which fed upon it. Like other aspects of the 'sovereign order of Nature', this idea was modified in the light of observation, but it played an essential part in

directing attention to the phenomena of biological adaptation and of ecology, which were to become so important in later discussions of evolution.

EIGHTEENTH-CENTURY THEORIES

A full discussion of the transition from this conception of an essentially fixed order of nature, established at the Creation, to the modern idea of organic evolution would have to take account of the intimate interaction between this idea and the idea of progress developed by eighteenth-century historians. The parallelism between them is striking. Both asserted the fact of development in time; both offered laws of development, on the model of Newton's laws of motions. It would be difficult to find a better example of the unity of thought so often shown during certain periods of history by different branches of knowledge.

By the middle of the eighteenth century enough evidence had accumulated from various lines of research to make some of the best biologists dissatisfied with the static conception of fixed species, and to lead them to the view that the 'scale of nature' described by systematists had been produced by a process of evolution in time. Suggestions that limited kinds of organic evolution had occurred had in fact never been entirely forgotten since they were first made by some Greek philosophers before Aristotle.

A first fundamental point of criticism concerned the conception of a biological species. The French biologist, Buffon, in the famous article on "The Ass" in his *Natural History* (1749), said of all the categories of the classification:

> "Nature . . . knows none of these spurious families, and contains, in fact, nothing but individuals."

A species Buffon held to be not something real, but simply a *name* by which we designated, entirely for our own convenience, individuals with a certain degree of resemblance, common descent, and the ability to produce fertile offspring when mated. This conception of species established the important point that varieties, and hereditary differences observed between individual offspring and parents, could be used as evidence that evolution was possible.

Actual evidence that hereditary changes did take place came from breeders of garden plants like strawberries and tulips, and of fancy breeds of pigeons and dogs. Linnaeus himself was forced to modify his original ideas to admit of a limited degree of change in species within fixed genera. Inherited abnormalities in human beings, for example albinism in negroes, and polydactyly, were also described.

Palaeontological evidence to show that as a matter of fact the species of organisms living at different periods had changed in the course of time had been discussed in the seventeenth century by Robert Hooke (though long before him some writers—Anaximander, Avicenna, Albertus Magnus, Leonardo da Vinci—had recognised the true nature of fossils). "There have been many other species of creatures in former ages, of which we can find none at present", wrote Hooke; "there may be divers new kinds now, which have not been found from the beginning." Buffon gave a first account of the succession of organic forms in geological strata in his *History of the Earth* (1744), and a fuller account in *Epochs of Nature* (in 1778). He observed that fossil plants in coal measures and fossil fish in slate differed from modern forms; he also noted that mammoths and some marine animals had become extinct. He concluded that each geological epoch had its distinctive climate and its distinctive flora and fauna, and that in the transition from one epoch to the next some forms died out and others became modified to suit the new conditions.

The earliest explicit statement that *all* organisms have evolved by descent from common ancestors was also made by Buffon in the same article. He pointed out that the essential similarity of structure observed in a group like the vertebrates could be explained by supposing that all vertebrates had descended, with modification, from the same original ancestors. He suggested:

> ". . . that the ass belongs to the family of the horse, and differs from him only by modification . . . that man and the monkey have sprung from the same common stock, like the horse and ass; that each family, either among animals or vegetables, has been derived from the same origin, and even that all animated beings have proceeded from a single species, which, in the course of ages, has produced, by improving and degenerating, all the different races that now exist."

Buffon suggested various causes for the modification of organisms, mainly by the influence of climate and food, but by far the most interesting of the eighteenth-century causal theories of evolution was that put forward by another Frenchman, the mathematician Maupertuis. In 1744 Maupertuis had examined an albino negro boy brought to Paris from South America. The following year, in a work called *Venus Physique*, he put forward a genetical theory to explain "the production of accidental varieties, the succession of these varieties from one generation to another, and finally the establishment or destruction of species". This theory he generalised in another work, *Système de la Nature* (1751), and used to explain the origin of all existing species.

Maupertuis' theory was explicitly an attempt to give a causal explanation of the emergence of novelty. Influenced by current views on the structure of matter, he supposed that all material bodies were composed of elementary particles; new characteristics he attributed to rearrangements of these persisting particles. To overcome the difficulty that from conceptions and laws of matter and motion framed to describe only inorganic phenomena, it was impossible to deduce such a phenomenon as the intelligent behaviour shown by animals, he adopted an idea from Leibnitz and endowed the elementary particles themselves with a degree of intelligence. The increasing mental powers observed in passing up the organic scale from minerals to Man he then explained by supposing that, as they united to form more and more complicated organisms, the individual perceptions of the elementary particles would combine to produce intellectual powers that were essentially new.

To explain the inheritance of both physical and mental characteristics Maupertuis put forward a theory of 'pangenesis'. He supposed that the embryo developed from the union of the seminal fluids of the two parents (the

role of cells in reproduction was then not well understood); each fluid contained particles derived from all parts of the parent; on mixing, the particles from each parent united in pairs to produce the embryo.

Organisms with novel characteristics might then have arisen in the past either by fortuitous changes in the seminal fluids, "in which the elementary particles did not keep the order they had in the father and mother animal"; or by changes induced by the environment, for example by climate, food or mutilation. Both kinds of changes would be inherited by pangenesis. "Each degree of error would have made a new species, and as a result of repeated variations would have been made the infinite diversity of animals we see today." But, he said in his last work on the subject, *Essai de Cosmologie* (1756), in a passage which anticipated the theory of natural selection:

> "in the fortuitous combination of the productions of Nature . . . only those with certain adaptive relationships could survive . . . in the other, infinitely greater part, there was neither adaptation nor order. All these last have perished . . . and the species we see today are only the smallest part of those which a blind destiny produced."

This conclusion was diametrically opposed to the traditional picture of an organic world created by God in a state of self-regulating harmony, in which each creature was made perfectly adapted to its way of life. Adaptation was achieved only by a process of struggle and elimination; order was brought out of chaos when, to quote Shakespeare's words, "Each thing meets in mere oppugnancy".

Of the several other discussions of organic evolution made in the second half of the eighteenth century, the most systematic was that by Erasmus Darwin, but his ideas were almost immediately overshadowed by those of Lamarck, published in their classical form in his *Philosophie Zoologique* in 1809. His theory of evolution was designed to account for two distinct phenomena. The first was the progressive development of organisms observed in ascending the 'scale of nature'. This he attributed to a basic tendency of all living matter to increase in size and complexity with the lapse of geological time. The second phenomenon was the divergent evolution of plants and animals with the same basic structure; the different modifications in the form and function of individual organs which could be seen in different species within the same genus, for example, he considered to have arisen as adaptations to different environmental needs. Instead of saying, like Maupertuis (and later Charles Darwin), that most varieties arose by *fortuitous* changes in the germ and that those which *happened* to be better adapted survived, Lamarck said that organisms varied in *direct response* to the demands of the environment, so that all variations were adaptive *from the start*. The manner in which this happened he described by his well-known 'law of use and disuse'. For example, the giraffe developed a long neck by stretching it to browse on trees; ducks developed webbed feet from spreading their toes in swimming; snakes lost their legs, and moles their eyes, through disuse, only vestiges of the full organs remaining. This 'law' assumed that new characters acquired by the individual were inherited and so became properties of the race; it was this assumption of the 'inheritance of acquired characters' that became the centre of controversy when 'Lamarckism' was revived at the end of the nineteenth century.

THE CONTRIBUTION OF GEOLOGISTS AND COMPARATIVE ANATOMISTS

Although a strong reaction set in against the theory of evolution during the first half of the nineteenth century, partly because of the inadequacy both of the evidence for it as a historical fact (for example the geological record was singularly poor in intermediate varieties—the 'missing links', as they were later called) and of the causal explanations available, and partly because biologists for a time found it more satisfying to return to non-evolutionary methods of correlating their data, two lines of research played an essential part in preparing the ground for Charles Darwin.

First, the study of comparative anatomy contributed two fundamental ideas. One was the so-called 'principle of the correlation of parts' enunciated by the great French zoologist, Cuvier. He pointed out that all the main organs in any animal were functionally interdependent, so that the whole was adapted to the animal's way of life. For example the sense-organs, brain, limbs, jaws and digestive system of a carnivorous mammal are all integrated together, and the integration of functions is indispensable for the animal to be able to perceive, catch, eat and digest its prey. He held that it was possible to establish general laws of correlation, like the laws of physics, so that if, for example, fossil teeth or an incomplete skeleton were discovered, the whole animal could be reconstructed, "just as the equation of a curve implies all its properties", as he put it in his *Ossemens Fossiles* in 1812.

The other fundamental idea was that of the 'ideal archetype', contributed by an opposing school of comparative anatomy led by Goethe, Étienne Geoffroy Saint-Hilaire and Richard Owen. This school showed how all the animals belonging to a group like the ape family, or the vertebrates as a whole, could be derived from a single archetypal ape or vertebrate by geometrical changes in the shape and position of the parts. Extreme members of the school took the view expressed by Geoffroy when he wrote, in 1835: "There is, philosophically speaking, only a single animal", a single archetype from which the whole animal kingdom could be derived. The idea of the ideal archetype had the most important results. For example, arguing that all members of a group must possess the same parts as the archetype of the group, Geoffroy was led to discover teeth in the embryos of birds, Reichert to establish the correspondence, or 'homology' (a word introduced by Owen), between the bones of the gill-arches of fish and the bones in the ear of land-vertebrates, Savigny to establish the homology between crustacean limbs and the mouth-parts of insects. The so-called 'law of parallelism', according to which each animal in the course of its embryological development recapitulated its evolution by passing through all the stages below it in the animal scale, also came from this school. It was an easy step to interpret the succession of geometrical transformations proposed by the comparative anatomists as corresponding exactly to the

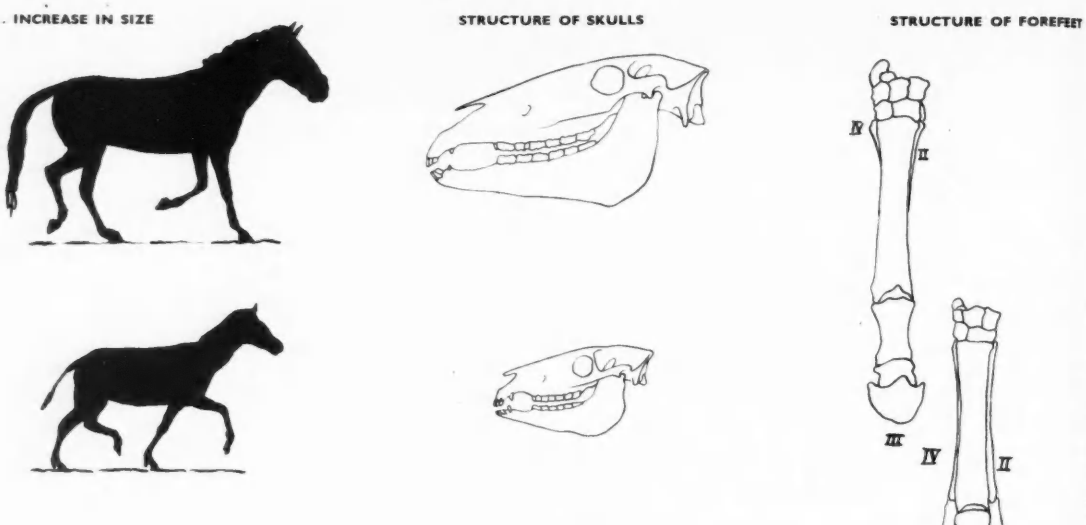

FIG. 2. The stages in the evolution of the Horse as worked out from the fossil record. The ancestor of the horse was *Hyracotherium* (bottom), followed by *Mesohippus* and *Merychippus*. The changes which occurred in the structure of the skull and forefeet are indicated.

series of stages making up a process of historical evolution, in which the ideal archetype became a real ancestor.

Charles Darwin was eventually led to interpret the ideal archetype in this manner by a second line of research—the geological. The geological discoveries made between James Hutton's *Theory of the Earth* in 1795 and Sir Charles Lyell's *Principles of Geology* in 1832 provided, for the first time, detailed and systematic knowledge of the geological record, showing the succession of species in different strata of rocks, and established the so-called 'uniformitarian' view that geological changes in the past were brought about by the same forces as could still be observed.

THE DARWINIAN REVOLUTION

Charles Darwin had the great good fortune to write for contemporaries already prepared to be persuaded of the truth of evolution. His own contributions to evolutionary theory, made in his classic *On the Origin of Species* (1859), were, first, to present in all its full detail the evidence that a historical process of evolution had occurred; and secondly, to advance an acceptable causal theory to explain the process. By a coincidence, A. R. Wallace independently arrived at the same theory at the same time.

Darwin's causal theory involved three main factors. First, he took from the economist Thomas Malthus the idea that populations of organisms increased up to the limit of their food supply, when there was a "struggle for existence", not only for food but also for other necessities for life. In this struggle only a proportion of any generation could survive. Secondly, he showed that there were hereditary differences in the degree of adaptation to the environment between individuals of the same species. Thirdly, he concluded that in each generation there would be a statistical probability of the "survival of the fittest", that is of individuals with the most favourable variations. This process Darwin called "natural selection", by analogy with the artificial selection that had produced the different breeds of domestic plants and animals. Though the hereditary variations *originated* without any necessary connexion with adaptive requirements, it followed that so long as they continued to arise and produce differences in adaptation, evolution *must* occur and must lead organisms to diversify so that they became adapted to diverse environments.

By presenting his evidence in such lucid and cogent detail, Darwin brought about a revolution in biology which was comparable with the 'Newtonian' revolution in physics

at the end of the seventeenth century. Biology now had a great unifying hypothesis; the 'scale of nature' described in the classification, the geological record (see Fig. 2), and the adaptation of organisms to their environments were all explained by evolution by natural selection.

The next stage towards the completion of the modern 'Darwinian' theory of evolution came with the establishing of the genetical theory known as Mendelism. Darwin himself had been unable to show convincingly how a new variety would avoid disappearing in a few generations when crossed with other forms; it seemed that the characters of the new variety would become blended with the normal characters of the species and would thereby become obscured. Mendel's 'laws' established the important point that the hereditary characters shown by organisms are determined by 'factors' in the germ cells which retain their identity from one generation to the next, in hybrids as much as in pure-bred forms. This is called the 'particulate' conception of heredity. Work in the present century has shown that genes tend to 'mutate', producing offspring with new characters, at definite rates; these mutations are the hereditary variations on which natural selection operates in a manner that can now be expressed by precise mathematical laws.

In spite of all this advance, not only the modern genetical theory of natural selection, but also the whole concept of evolution, raise peculiar problems of which the solution is by no means always obvious. To take a simple example, evolution offers a meaning for the conception of a 'natural' classification, as one showing how the historical process of evolution has taken place. But, except for the minority of cases where palaeontological evidence is available, the only means of obtaining any detailed knowledge of the historical process is to deduce it from a comparison of modern forms, whose relationships we determine not by their evolutionary history, which we do not know because the fossil record has not been found, but by their observable likenesses and differences.

Another problem is the evolution of adaptation from initially non-adaptive mutations. The 'Lamarckian' explanation of the evolution of adaptation through the inheritance of acquired characters has been rejected, at least in its old form, because all attempts to demonstrate such inheritance experimentally have failed. Viewing the subject historically, it is also important to note that faith in the inheritance of acquired characters was destroyed by Weismann's theory of the 'continuity of the germ plasm', put forward in 1887. Weismann maintained that germ cells arose only from other germ cells, so that characters acquired by the body cells could not be passed on to another generation. In 1902 Sutton showed that, when germ cells were being produced, small elongated bodies known as 'chromosomes', observed in the nucleus of cells, behaved in such a way that they could carry the Mendelian 'factors'. These factors, or 'genes' as they came to be called, were later shown to be arranged in a definite order on the chromosomes, like beads on a string. Put in modern terms, Weismann's theory means that genes arise from other genes, and that changes happening to the body of an organism are not represented in the genes and so are not inherited. No doubt the evolution of adaptation will be better understood when more is known about how genes control the development of the embryo.

Two other problems affect the most fundamental intentions of the theory of evolution. The first is to find a deductive explanation of the most striking feature of the whole process, the emergence of new characteristics like the increasing intelligence observed in the series of animals from fish to apes, culminating in abstract thinking in Man. Speculation about this has usually claimed that such new characteristics would arise as a result of rearrangements of persisting parts, for example genes, the novelty being a product of the organisation. A theory from which new characteristics observed only in the later stages of a process could be deduced would involve the old difficulty, discussed by Parmenides and Aristotle, that it would have to postulate that these characteristics were somehow inherent in the earlier stages, where they were not observed.

The second problem is that the actual historical evolution that has occurred on the earth is a unique series of events, happening once and for all, and it is impossible to deduce such a unique series from a general theory without knowing the specific conditions obtaining at the particular times and places involved. Since these are not necessarily constant, and can be known only by special research, it is impossible, either from a causal theory like natural selection, or from a theory of a trend based on observations over a given period of time, to deduce a course which evolution *must* follow. And since there cannot be a universal law of the *actual* evolution that does occur, the metaphysical and ethical speculations which have been based on the existence of such a law, such a "world process of evolution", lose their essential premises.

Heir as it was to the creation myths of Babylonian religion and to the cosmogonies of the earliest Greek philosophy, and twin sister of the modern historical doctrine of progress, the scientific theory of organic evolution was inevitably stretched to explain more than it can in the enthusiastic half-century following the *Origin of Species*. Few echoes remain of those controversies. As a contribution to science, the theory has done as much as may reasonably be expected of any scientific theory: it has provided a new way of making things intelligible, and it has given direction to research. It takes its place as the latest of the great stages in this history of scientific explanation, created by revolutionary acts of imagination and reasoning, and surviving as part of science by unremitting criticism.

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Far and Near

"Discovery" articles in the Smithsonian Report

Every annual report of the Smithsonian Institution makes an imposing bound volume, the latest (for 1951) containing 450 pages. The famous 'general appendix', which takes the form of a selection of major articles from the world's scientific press, occupies two-thirds of the book. There are twenty-one articles in the 1951 report, including five British articles, two of which are reprinted from DISCOVERY.

British Association's New President

Sir Edward Appleton has succeeded Prof. A. V. Hill as president of the British Association.

Born 1892, he was educated at Hanson School. He graduated at Cambridge just before World War I started, and during that war he served as wireless officer in the Signals Section of the Royal Engineers.

Afterwards he returned to Cambridge to join Sir J. J. Thompson's staff at the Cavendish Laboratory, and began his investigations to explain the then puzzling phenomena of radio-signal fading. In 1924 he was appointed—at the age of 32—Wheatstone Professor of Experimental Physics at King's College, London, where he remained until 1936. The existence of the Heaviside-Kennelly layer was proved by Appleton's experiments on December 11, 1924. Later he penetrated the Heaviside layer and proved the existence, 120 miles up, of the so-called 'Appleton Layer'. These discoveries earned him the Nobel Prize for Physics in 1947.

In 1932–3 he led a Radio Research Expedition to Norway, and results of this research project included the discovery of the 11-year cycle of sunspot activity.

He joined the D.S.I.R. as its secretary in 1939, and proved in succeeding years his administrative capacity as director of this great scientific organisation.

Sir Edward is now Principal and Vice-Chancellor of Edinburgh University.

He has already announced his intention of delivering *two* presidential addresses at this year's Liverpool meeting of the British Association, arranged for the week September 2 9. There will be the presidential address proper, and later he will give a special address to the junior members. The junior membership was introduced at the Belfast meeting last year, and it attracted some 900 school children. At Liverpool, special junior lectures are again being arranged, and it is hoped that about a thousand young students will attend them.

Cheralite: A New Radioactive Mineral

The discovery of a new kind of mineral very rich in the radioactive elements thorium and uranium was announced to the Mineralogical Society in January by S. H. U. Bowie and J. E. T. Horne of the Geological Survey and Museum. The mineral, containing 31% thorium oxide and 4% uranium oxide, has been named cheralite—from Chera, the ancient name of the State of Travancore in South India where the new mineral species was found. This deposit of the mineral is far too small to be of any commercial importance, however. A specimen of the new mineral is displayed in the Geological Museum, South Kensington. Dull green in colour, it is mineralogically related to monazite, commonest ore of thorium.

Manufacture of Film Base: A New British Industry

Modern non-inflammable film base is made of cellulose triacetate, a material allied to acetate rayon but of higher tensile strength and water resistance. But it has not been produced in Britain, so that British factories making photographic films have had to rely on supplies of film base imported from abroad, mainly from the U.S.A. This fact, coupled with restrictions on dollar expenditure, has cramped production of photographic film, which has not been able to expand to meet fully the rising demands. This explains why, for example, the increased demand for X-ray film by British hospitals has not been satisfied.

It has now been announced that a British plant making the triacetate film base is operating and will soon be in full production. This plant, jointly owned by Ilford Ltd. and BX Plastics, is located at Brantham in Essex.

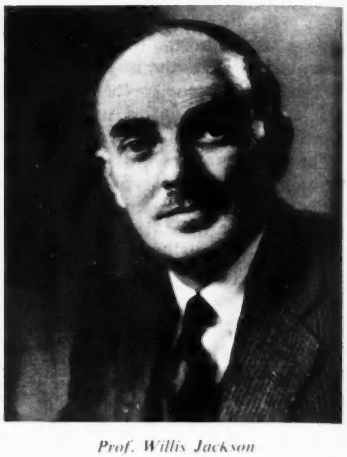
The end of the X-ray film shortage is now in sight, and it is estimated that the output of this factory will enable Britain to dispense each year with a million dollars' worth of film imports from America.

Defence Scientists meet in Delhi

The Commonwealth Advisory Committee on Defence Science meets in New Delhi this month. Britain's delegates will be led by Sir John Cockcroft, who is Scientific Adviser to the British Ministry of Defence, and will include scientists from the Navy, Army and Air Ministry. Canada is sending Dr. O. M. Solandt, who was present at the Monte Bello atomic bomb tests.

New Defence Research Appointment

Dr. Walter Cawood has become Principal Director of Scientific Research (Defence) in the Ministry of Supply in succession to Dr. O. H. Wansbrough-Jones, who succeeds Sir Harry Garner as Chief Scientist at the Ministry. Dr. Cawood, who is 45, has been a Deputy Director at the Royal Aircraft Establishment since 1947. Educated at Leeds University, he entered the Civil Service in 1938 as a scientific officer. He served with the Air Ministry and the Ministry of Aircraft Production before entering the Ministry of Supply.



Prof. Willis Jackson

Metrovick's New Director of Research and Education

Professor Willis Jackson, Professor of Electrical Engineering at the Imperial College of Science and Technology, has accepted the full-time appointment of Director of Research and Education of Metropolitan-Vickers Electrical Co. Ltd. as from July 1 next. He will take over from Dr. C. Dannatt, the present Director of Research and Education, who succeeded Sir Arthur P. M. Fleming in that position.

Radar Detection of Icebergs

Icebergs can be detected by standard marine radar sets at distances ranging from 20 miles down to 1¼ miles, depending on the size. 'Growlers', which protrude up to 10 feet above sea level, can be detected at ranges not exceeding 3 miles, which gives a 12-minute warning for a vessel moving at 15 knots. These figures, which were given at a recent Institute of Navigation meeting, were obtained in a British-Canadian trial, using a standard type radar set on an icebreaker which made a 5000 mile voyage in the Belle Isle and Hudson Straits last summer.

"Underground Gasification"

In the article on Underground Gasification in our January issue, page 6, line 19 from bottom right-hand column, the word 'surface' at the end of the sentence should have read 'fire gallery'.

Expansion of Central Public Health Laboratories

A large new block of laboratories has been opened at Colindale, giving more accommodation for the technical headquarters of the Public Health laboratory service controlled by the Medical Research Council. The scientific staff of these laboratories are concerned with problems connected with the prevention and control of infectious diseases.

The top floor of the new building is devoted to work on virus diseases, and incorporates special features designed to minimise the risk of the scientists being

infected by the viruses they study. For example, a positive pressure of sterilised air is maintained in some rooms so that on opening the door there can be no contamination from the air outside; in others negative pressure ensures that no harmful virus or bacteria escape; these are drawn out and destroyed by hot furnaces in air ducts.

Night Sky in March

The Moon.—New moon occurs on March 15d 11h 05m, U.T., and full moon on March 30d 12h 55m. The following conjunctions with the moon take place:

March					
4d 23h	Saturn in conjunction with the moon		Saturn	8°	N.
17d 20h	Venus	,,	Venus	2°	N.
17d 20h	Mars	,,	Mars	5°	S.
19d 06h	Jupiter	,,	Jupiter	6°	S.

In addition to these conjunctions with the moon, Venus is in conjunction with Mars on March 17d 23h, Venus being 7° N.

The Planets.—At the beginning of the month Mercury sets at 19h 20m, and at 18h 45m at the middle of the month—only three-quarters of an hour after the sun in the latter case—and is in inferior conjunction on March 18 after which it becomes a morning star. On March 31 it rises at 5h 05m which is about 35 minutes before sunrise and is not favourably placed for observation. Venus is an evening star, setting at 21h 55m, 21h 45m and 20h 50m on March 1, 15 and 31, respectively, and is visible in the western sky for some time after sunset. The visible portion of the illuminated disk varies from 0·332 to 0·070 and the stellar magnitude averages about −4·2. The planet attains its greatest brilliancy, magnitude −4·3, on March 8, and is stationary on March 22. Mars is visible in the early hours of the night, setting at 21h approximately throughout March. In the middle of the month it is a little north of o Piscium and soon afterwards moves into the constellation of Aries. Jupiter sets at 23h 35m, 23h 20m and 22h 15m on March 1, 15 and 31, respectively, stellar magnitude −1·7, and lies a little south of δ Arietis during most of the month. Saturn rises at 21h 50m, 20h 50m and 19h 35m on March 1, 15 and 31, respectively, stellar magnitude 0·6, and can be seen during the night a little north-east of α Virginis.

Vernal equinox takes place on March 20d 22h.

From March 19 to 23 there will be occultations of a number of naked-eye stars by the moon, and the times of occultations for the two brightest of these are as follows:

March 19d 22h 34·0m, γ_1 Tauri, mag. 3; March 23d 23h 50·6m, ε Geminorum, mag. 3·2, reappearing at 0h 48·0m. The stars are occulted owing to the eastward movement of the moon in its revolution around the earth, and they can be seen until the left limb of the moon as you face her intercepts the light from the star.

Development of Inventions

The National Research Development Corporation was established by the Government in 1948, its prime function being to "secure, where the public interest so requires, the development or exploitation of inventions resulting from public research, and of any other invention as to which it appears to the Corporation that it is not being developed or exploited or sufficiently developed or exploited". By statute it is empowered to acquire, hold and dispose of patent rights in connexion with inventions which result from public research; it can also acquire rights in inventions from other sources (e.g. university and industrial research) where this is desirable in the public interest.

The Corporation's latest report gives some details of inventions in which it is interested. By the middle of 1952, the NRDC had acquired or applied for 1736 patents. Its special interest in electronic computors is evidenced by the fact that 479 patents have been applied for in respect of 99 inventions in this field. The report states that "our belief in the future importance of these machines is undiminished", and refers to a contract given by the NRDC for the supply of four machines similar to that designed by Prof. F. C. Williams at Manchester University. A development contract has also been placed for a prototype of another computing machine of very much reduced size.

The NRDC is developing diffraction grating inventions arising out of Sir Thomas Merton's original work. Development work is proceeding at the National Physical Laboratory with NRDC support. The Corporation has licensed two scientific instrument firms to use the patents it holds on these inventions, and this is expected to lead to export orders.

Another NRDC contract provides for development work on light steam engines fired by low-grade fuel and intended for underdeveloped areas where small prime movers are urgently needed. This project originated in a proposal made by Sir Harry Ricardo, who is now engaged in the research and development work required to bring the idea to practical fruition.

The report mentions the fact that Britain produces no instruments which can be used to prepare contour maps from stereoscopic aerial photographs. (The instrument which was shown carrying out this work in the recent DISCOVERY article "Mapping Greece from the Air", December 1952, was of German origin.) An invention of Col. Thompson, Professor of Surveying at University College, London, offers the prospect that a British instrument to do this work could be designed, and this is now the subject of a joint enterprise by the NRDC and an industrial firm on a risk-and-profit-sharing basis.

O. N. Witt: Father of Colour Chemistry

The centenary of Otto Nikolaus Witt, born on March 31, 1853, should be of particular interest in Britain because this brilliant organic chemist not only discovered valuable dyes while working at Brentford, but also in his English period published his classic study "On the Relation between Chemical Constitution and the Colour of Organic Compounds". William Henry Perkin is remembered as the father of coal-tar dyes; Otto Witt's claim to fame rests on the theory of colour, which he proposed and which has served to guide research on dyestuffs. Perkins won fame at his Greenford works: and Witt discovered chrysoidine and a series of dyes called the Tropacolines while he was with the Brentford colour works of Williams, Thomas and Dower.* Moreover, the several dyes which he discovered and his classic theory of colour formed only part of his contribution to the cause of chemistry. A second phase of his career opened in 1885, when he left industry to become Germany's foremost teacher of industrial chemistry.

Witt was as international in his associations and contacts as he was versatile in chemistry. He came of Russian stock, his father being at one time professor of chemistry at St. Petersburg. Yet Witt himself was of Swiss nationality since his parents had moved to Zürich and had become naturalised there. They sent their son to the Polytechnic in that city, where his teachers included Victor Meyer, Kopp and Wislicenus.

After a short spell in a Duisburg ironworks, Witt returned to Zürich, took a post in a printing works where contact with both natural and artificial colours no doubt influenced his later work. 1875 saw him in Brentford, and a year later came his tropaeoline dyes. These were among the first practical azo-dyes, along with Poirrier's oranges discovered in Paris and 'Manchester Brown', which became Bismarck Brown when the German interests teutonised the name. Witt also discovered Tolylene red and Tolylene blue while at Brentford. In 1886 he put forward his theory of Colour and Constitution. He noted that every dye appeared to have in its structural formula a colour-bearing group of two or three atoms. Such groups all included double bonds as in N N, C=C or N O, the first being called 'azo', the second 'ethenyl', and the third 'nitroso'. Witt called such groups 'chromophores'—from the Greek *chroma* or colour, and *phoros* signifying 'bearer'. On increasing the number of such chromophoric groups within the molecule a

* This factory was known as the Star Chemical Works, and manufactured coal-tar colours until 1877. The enterprise was then transferred to a new factory at Hounslow; the firm then became known as William Bros. & Co., later being reconstituted under the present title of Williams (Hounslow) Ltd.

deepening of colour resulted. Witt went further by discovering that for practical purposes—as, for instance, in dyeing—the effect of such chromophores could be intensified or strengthened by introducing other groups which he called 'auxochromes'. Such additional groups (e.g. NH_2, $-NHCH_3$ and $-OH$) were well known to confer basic or acidic properties on the compounds containing them; hence they formed soluble salts with acids or alkalis and enabled soluble dyes to be prepared. This double purpose of improving solubility and intensifying colour-depth was exceedingly valuable, and the compound combining the two types of groups, that is, both chromophore and auxochrome, was given the name of 'chromogen' irrespective of whether it was a useful dye or merely a chemical compound of purely academic interest. Thus it was that Witt, the successful dyeworks chemist, gave a fundamental theory, which inspired much subsequent research and posed many problems which have still to be solved. To round off this impression of Witt's versatility, tribute must be paid to his twenty-five years as teacher of applied chemistry, notably at Charlottenburg.

M. SCHOFIELD

THE BOOKSHELF

Professional People by Roy Lewis and Angus Maude (*London, Phoenix House, 1952, 284 pp., 18s.*)

In their earlier book, *The English Middle Classes*, the authors examined the changed position of the middle classes as a whole, and produced a scholarly and entertaining study of contemporary British life. The present volume examines in detail the large section of the middle classes engaged in the professions. The professional classes are worse off than formerly; how this state of affairs came to be, and the future prospect for the professions, forms the theme of the book.

The political and industrial trend towards collectivism, accelerated by six years of war and six years of Socialist government, has resulted in a greatly increased demand for professional experts, yet it has also resulted in a deterioration of the experts' economic position. The combination of these two factors tend, in the authors' view, to produce an ever decreasing level of professional status and material prospects. The greatest threat to professional standing has been caused by 'dilution' the demand for new professions is growing, and inevitably professions to supply the demand are manufactured.

The authors' remarks about frustration in the nationalised industries are disturbing, and reaches its height in the discussion of the National Coal Board. The conclusion is reached that 'experts' have inherited the leadership in Britain and have assumed for themselves the status which was formerly reserved for the older professions. This leadership will be in good hands only if the leaders remain professional in the best sense, that is retaining the old fiduciary relationship between the professional man and his client. To hold this conclusion, one must either take no account of the changed relationship of the professional man with his environment, or admit that many of the new experts have no claim to be admitted to professional status.

Indeed the vexed question 'What is a profession?' receives a great measure of attention. Since a big proportion of the new body of experts is made up of scientists, this book is of considerable interest to them in discussing whether the scientist in industry should remain "a clever devil from Birmingham" or should be admitted as a full professional member of society. The authors' researches into the education of the expert and their plea for broader education for the technologist are of particular interest to the scientific reader. Technology in this country, in the authors' view, shows signs of withering at the roots due to the low salaries offered to science graduates in teaching and the 'specialism' of teaching itself. This point of view has often been expressed in DISCOVERY but loses none of its force by being emphasised to the different public which this book will command.

Whatever view is taken of the political and social events of the last twelve years, and the strongly conservative conclusions reached by the authors, they have rendered good service in amassing a fund of knowledge on the recent development of the professions which was not available before. This is a book which every scientist ought to read.

The Creation of the Universe by Professor George Gamow (*New York, Viking Press; London, Macmillan, 1952, 147 pp., 21s.*)

The Sky and its Mysteries by E. Agar Beet (*London, G. Bell & Sons, 1952, 237 pp., 15s.*)

Our Neighbour Worlds by V. A. Firsoff (*London, Hutchinson's Scientific & Technical Publications, 1952, 336 pp., 25s.*)

Non-mathematical books on astronomy tend to fall into two large and distinct classes. On the one hand there are the books which, keeping close to the known facts, describe not only the results of observation but the methods and difficulties of observing, while on the other there are those sweeping surveys of the Universe which seldom mention the practical difficulties of astronomy and sometimes err on the side of presenting tentative hypotheses as though they had the status of well-established theories. Two of these three books can be classified without hesitation—Mr. Beet is most careful to base all his statements on observational work, while Professor Gamow ranges far and wide, from atomic nucleus to galaxy, from past to future, with a dash that is exhilarating but hardly convincing. The mode of creation favoured by the Professor is the cosmic explosion, similar to that suggested by Canon Lemaitre, but differing in the initial conditions; instead of Lemaitre's "primeval neutron" we have a mass of intensely hot, very dense, nuclear material. This nuclear gas—its temperature is high enough for its properties to be those of a gas—is at no time in equilibrium, and it is the result of a previous collapse whose cause is not investigated. Estimates are made of the density and temperature of the gas and of the time of the initial explosion, followed by a discussion of the results, particularly the creation of the different elements in the proportions in which, according to the writer, they occur. The subsequent evolution of uniformly distributed gas, dust and radiation into galaxies and stars is presented as a succession of eddy formations on the von Weizacker model and is pursued in some detail up to the formation of planets and their satellites. Other theories are mentioned in a cursory manner, Lemaitre, Hoyle, Bondi, Gold and Lyttleton all receiving a few hard raps and what appears, in a few cases, to be rather cavalier treatment.

Professor Gamov presents his theories in a lucid and direct form, with many diagrams in the lively style well known to readers of his other popular books, and with mathematics confined to footnotes and a four-page appendix. The treatment is at a level suitable for anyone whose science is of 'sixth form' standard but is not too 'popular' to repel the specialist in another branch. The book contains several small lapses (such as the confusion between mass and weight on page 90, and an inaccurate statement about the speed of sound on page 87), but its greatest weakness seems to lie in the assumption that the observational data at our disposal is quite accurate and conclusive as to the relative abundance of elements in the Universe, the equipartition of energy between galaxies, and so on. While accepting the need to simplify in a book of this type it should be possible to give some indication of the amount, nature and reliability of the observational evidence—without it the work loses much of its value but fortunately none of its interest.

Mr. Beet's new book is of a totally different type—he writes for a wider public with the object of instructing in the methods as well as in the theories of astronomy. It can be said at once that he has produced an excellent and absorbing book, well indexed and containing extensive lists of references. The book begins with a survey of the "raw material" of astronomy and of the early attempt to account for planetary phenomena; this is followed by a chapter devoted to instruments, including the Schmidt camera, the spectro-helioscope, and the photo-electric photometer (a glaring inaccuracy over the size of Schmidt's first instrument occurs

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here), and the next two chapters deal with the Earth-Moon system and the Solar System. This leaves three chapters for stellar astronomy, at first sight a small allocation of space but one that is consistent with the practical approach adopted by the writer; a reader possessing only a pair of binoculars is naturally much more interested in the Moon and planets than in spiral nebulae or white dwarfs.

In his discussion of the origins of stellar energy and of the planets the writer is perhaps too brief—the theory of von Weizacker should surely have been given as much room as the tidal theory of Jeans. Taken as a whole, this is a very good introduction to astronomy.

The third volume seems to have a foot in both camps—it contains an astonishing amount of up-to-date and accurate information mixed up with a very optimistic view of the possibilities of rocket travel to the Moon and planets. After a brief introduction and a glance at the planetesimal and tidal theories, Mr. Firsoff introduces his own theory in which the parent star produces a series of gaseous shells, which, after condensation and accretion, form the planets. Support for this theory is sought in the relationship between mean densities of planets and their distances from the Sun—it is suggested that the less dense elements would be projected farther from the star and that therefore the more distant planets may be expected to be less dense than those nearer the Sun, as indeed they are, Pluto excepted. Pluto is regarded as the inner, and therefore dense, remnant of a previous and more violent ejection of matter, which also helps to raise the densities of Uranus and Neptune.

The problems of space travel are well discussed, apart from an unfortunate digression on magnetism and "negative matter". In the second half of the book we find the really valuable information about the planets, including the results of much recent work not previously available in books of a popular type. It is to be regretted that such good material is presented in so jarring a style and with such a liberal sprinkling of inaccuracies. Bodies do not exert gravitational attractions as if their masses are concentrated at their centres of gravity (p. 25)—the spectrum has no "purple" end (p. 69), the significance of rest mass when velocity approaches that of light seems to be exaggerated on p. 96—and there are many more. Even in the Appendix we find a confusion between cosine and cosecant that leads to an absurdity.

A striking similarity between these three markedly different books is in their assumption that the Earth has a core composed of iron and nickel—are all three authors quite ignorant of the work of Drs. Ramsey and Bullen? G. F. WEST

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ASSISTANT (SCIENTIFIC) CLASS: The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to 31st December, 1953, but an earlier closing date may be announced either for the competition as a whole or in one or more subjects.

Candidates must be at least 17½ and under 26 years of age on 1st January, 1953, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted.

All candidates must produce evidence of having reached a prescribed standard of education, particularly in a science subject, and of thorough experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces, covering a minimum of two years in one of the following groups of scientific subjects:

(i) Engineering and physical sciences.
(ii) Chemistry, bio-chemistry and metallurgy.
(iii) Biological sciences.
(iv) General (including geology, meteorology, general work ranging over two or more groups (i) to (iii) and highly skilled work in laboratory crafts such as glass-blowing).

Salary according to age up to 25: £236 at 18 to £363 (men) or £330 (women) at 25 to £500 (men) or £417 (women); somewhat less in the provinces. Opportunities for promotion.

Further particulars and application forms from Civil Service Commission, Scientific Branch, Trinidad House, Old Burlington Street, London, W.1, quoting No. S59/53. Completed application forms should be returned as soon as possible.

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The posts are divided between following main groups and subjects: (a) Mathematical and Physical Sciences, (b) Chemistry and Metallurgy, (c) Biological Sciences, (d) Engineering subjects and (e) Miscellaneous (including e.g. Geology, Library and Technical Information Services).

Age Limits: For Experimental Officers, at least 26 and under 31 on 31st December, 1953; for Assistant Experimental Officers at least 18 and under 28 on 31st December, 1953. Extension for regular service in H.M. Forces.

Candidates must have obtained, or be taking examinations during 1953 with a view to obtaining, the Higher School Certificate with mathematics or a science subject as a principal subject, or the General Certificate of Education in appropriate subjects, or the Higher National Certificate or other specified qualifications. Candidates without such qualifications may be admitted exceptionally on evidence of suitable experience. Candidates over 22 will generally be expected to have higher qualifications.

Inclusive London salary scales:

Experimental Officers £628–£786 (men); £533–£655 (women).

Assistant Experimental Officers £274–£586 (men); £274–£490 (women).

Starting pay according to age up to 26. At 18, £274; at 26, £495 (men), £467 (women). Somewhat lower rates in the provinces.

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COMMONWEALTH OF AUSTRALIA COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION ATOMIC ENERGY RESEARCH

Appointment No. 4157

THE COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANISATION invites applications from highly qualified

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for appointment to its research staff in the field of development of atomic energy as a source of industrial power.

It is proposed to appoint one Senior Principal Research Officer and a number of officers in the ranges of Principal Research Officer, Senior Research Officer and Research Officer. The salaries appropriate to these ranges are:

S.P.R.O.—Within the range £A1856–£A2104 p.a. (actual), £A62 increments.
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R.O.—Within the range £A836–£A1244 p.a. (actual), thirteen increments.

Successful applicants may be required to spend at least two years in the United Kingdom undergoing training prior to taking up appointment in Australia.

Applications, referring to appointment No. 4157, and stating full name, place and date of birth, nationality, marital state, present employment, particulars of qualifications and experience and of war service, if any, accompanied by names and addresses of at least two persons willing to act as referees, and copies of not more than four testimonials, should reach the undersigned, from whom further details respecting the appointments are available, by the 14th March, 1953.

J. E. CUMMINS,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

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